TENNESSEE GEOLOGICAL SURVEY

BULLETIN 1

# Geological Work in Tennessee

By GEO. H. ASHLEY, and Others

BULLETIN 2

# Preliminary Papers on the Mineral Resources of Tennessee

By GEO. H. ASHLEY, and Others

# STATE OF TENNESSEE

## State Geological Survey

GEO. H. ASHLEY, State Geologist

Succeeded by

A. H. PURDUE

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# BULLETIN 1

(Geological Work in Tennessee)

A. THE ESTABLISHMENT, PURPOSE, SCOPE AND METHODS OF THE STATE GEOLOGICAL SURVEY.

By Geo. H. Ashley

B. BIBLIOGRAPHY OF TENNESSEE GEOLOGY, SOILS, DRAINAGE, FORESTRY, ETC.

By Elizabeth Cockrill

C. HISTORY OF GEOLOGICAL WORK IN TENNESSEE.

(Published in THE RESOURCES OF TENNESSEE, Vol. II. No. 5, under the title, The Growth of Our Knowledge of Tennessee Geology.)

By L. C. Glenn.

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# BULLETIN 2

(Preliminary Papers on the Mineral Resources of Tennessee)

A. OUTLINE INTRODUCTION TO THE MINERAL RESOURCES OF TENNESSEE.

By Geo. H. Ashley

B. THE COAL FIELDS OF TENNESSEE.

(Published in THE RESOURCES OF TENNESSEE, Vol. III., No. 1, under the titles, The General Features of the Tennessee Coal Field North of the Tennessee Central Railroad, and the Tennessee Coal Field South of the Tennessee Central Railroad.)

By L. C. Glenn and Wilbur A. Nelson

C. THE IRON ORES OF TENNESSEE.

(Published in THE RESOURCES OF TENNESSEE, Vol. II., No. 9, under the title, The Valley and Mountain Iron Ores of East Tennessee.)

By Royal P. Jarvis

D. THE MARBLES OF TENNESSEE.

By Chas. H. Gordon

E. PRELIMINARY REPORT UPON THE OIL AND GAS DEVELOPMENT IN TENNESSEE.

By Malcolm J. Munn

F. THE PHOSPHATE DEPOSITS OF TENNESSEE.. Not yet published.

By Lucius P. Brown

G. ZINC MINING IN TENNESSEE.

By Samuel W. Osgood

NASHVILLE
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1—A

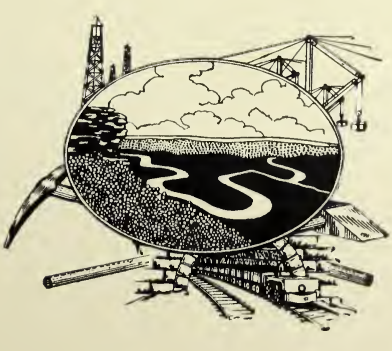
STATE OF TENNESSEE—STATE GEOLOGICAL SURVEY

GEO. H. ASHLEY, State Geologist

# THE ESTABLISHMENT, PURPOSE, SCOPE, AND METHODS OF THE STATE GEOLOGICAL SURVEY

BY GEO. H. ASHLEY

EXTRACT (A) FROM BULLETIN NO. 1, GEOLOGICAL WORK IN TENNESSEE



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# CONTENTS.

# THE ESTABLISHMENT, PURPOSE, SCOPE, AND METHODS OF THE STATE GEOLOGICAL SURVEY.

By Geo. H. Ashley.

## THE ESTABLISHMENT OF THE SURVEY.

The natural resources of any State or nation form the basis of its material advancement, and their development and use measure its wealth and progress. Tennessee is rich in mineral and other resources. Extending from the oldest rocks in the crest of the Appalachians to the newest rocks forming the bottoms of the Mississippi River, there is embraced within its borders a variety and richness of soils, of climate, of rock strata, of zones of ores and other minerals, hardly excelled by any other State in the Union. This is reflected in the fact that to-day she leads every other Southern State, except Alabama, in mineral production; that her mineral production in 1908 was larger than that of North Carolina, South Carolina, Georgia, Mississippi, and Arkansas, all put together; more than twice as large as that of Florida, and nearly twice as large as that of Louisiana, but, on the other hand, only a little more than half as large as that of Alabama.

And yet, with a few exceptions, she is making relatively little use of many of her resources, as compared with some other States no more favored, except by markets, and to a large degree Tennessee is one of the markets of those other States, rather than supplying her own needs. Thus, with probably as large deposits of clay as Ohio, she produces to-day only about one-twentieth as much value in clay products, and goes to Ohio and other States to supply more or less of her own needs. With probably as large deposits of suitable material for the manufacture of cement as Indiana, she produces only one-eighteenth as much, and makes a market for

more or less of Indiana's supply. With many times as much iron ore as Pennsylvania, she produces only one-twenty-eighth as much pig iron. And similar examples might be multiplied. But it is not alone in the getting out of the materials that an advance is possible, but as much or more in their use. Every pound of raw material shipped out of the State is simply supplying some other State with wealth-making opportunities. Michigan supplies raw iron ore worth, in 1908, $2.85 a ton, and Pennsylvania works it up into pig iron worth about $15 per ton, or into steel rails or other materials worth still more. To how large an extent is Pennsylvania's wealth based on the natural resources of other States? To how large an extent is Tennessee to-day supplying other States with their wealth?

In the industrial awakening which for the last ten years has been going on in the South, Tennessee has been a leading figure. The whole country is coming to a realization that to-day the South stands for opportunity much as did the far West thirty to sixty years ago. This is strongly reflected in the increase of population of the Southern cities; in the multiplication of industrial plants of all kinds; in the reclamation of swamp lands and abandoned farms; in renewed interest in education, art, and literature; and in a thousand minor ways. To-day capitalists looking for investments and young men looking for opportunities to worthily win their way have their faces turned toward the South, and the young men of the South no longer feel it to be necessary to go North or West to find the larger opportunity they desire.

Under these circumstances there is a growing demand for information. Men will go where they know the things they desire exist. The clay man seeking new investments will hardly come to Tennessee when he reads in Reis' "Clays—Occurrences, Properties, and Uses:" "Probably less is known regarding the clays of Tennessee than of any other Eastern State." (Page 420.) He will go to some place where he has learned authoritatively that the clays he desires exist, and under the conditions of transportation, etc., he needs. Therefore, if Tennessee is to maintain the preëminence she has held, it will be necessary, not alone that she realize more fully the extent of her own resources and the possibilities of their use, but that she publish these facts to the world. Who can tell how much of her present position in mineral production Alabama owes to the labors of the efficient State Geological Survey she has so long maintained?

It was a realization of these facts that led the State Legislature

of Tennessee, in 1909, to provide for the establishment of a State Geological Survey.

## THE BILL.

The bill establishing the Survey reads as follows:

CHAPTER 569.

SENATE BILL No. 300.

(By Messrs. Greer, Huffaker, and Neal.)

A BILL to be entitled An Act to establish and create the bureau to be known as the State Geological Survey; defining its objects, powers, and duties; providing for the appointment of a State Geologist, and defining his powers and duties; permitting coöperation with Federal and State bureaus in furthering the objects of this Act; providing for the publication of the results of the survey; providing for the collection of exhibits of the natural resources of the State, and for the final disposition of the equipment and property of the survey; authorizing entrance upon private lands in the prosecution of the work of the survey; and making the appropriations for the enforcement of this Act.

SECTION 1. *Be it enacted by the General Assembly of the State of Tennessee,* That there be, and is hereby, created and established a bureau to be known as the "State Geological Survey," which shall be under the direction of a Commission to be known as the "State Geological Commission," composed of the Governor (who shall be ex-officio Chairman of said Commission), the State Commissioner of Agriculture, the State Mine Inspector, the President of the University of Tennessee, the Chancellor of Vanderbilt University, and the Vice Chancellor of the University of the South.

SEC. 2. *Be it further enacted,* That the said Commission shall have general charge of the State Geological Survey and shall appoint as Director a Geologist of established reputation, who shall be known as the "State Geologist," and upon his recommendation such associate geologists, assistants, and employees as may be necessary to carry out successfully and speedily the work of the survey.

The Director, associates, assistants, and employees appointed under the provisions of this Act shall receive such compensation as shall be determined by the Commission. The said Commissioners shall serve without compensation, but shall be reimbursed for actual expenses incurred in the performance of their official duties.

SEC. 3. *Be it further enacted,* That the said Commissioners shall meet for organization within thirty days after the passage of this Act, and shall appoint a Director as soon thereafter as possible. The regular meetings of the Commission shall be held on the first Wednesday in May and the first Wednesday in November of each year in such place as the Commission shall determine.

SEC. 4. *Be it further enacted,* That it shall be the duty of the State Geologist, subject to the approval of the Commission, to organize and direct the work of the State Geological Survey in field and office; to determine the character, order, and time of publication of the reports of the survey, and to direct the prepara-

tion, printing, and distribution of the same; to arrange for coöperative work with the various Federal and State scientific bureaus where such work shall redound to the interest of the people of the State; to appoint such associates, assistants, and employees as may be necessary to carry out successfully and speedily the work of the survey; to procure and have charge of the necessary field and office supplies and other equipment, and supervise the acquisition, care, and distribution of the collections of the State Geological Survey; and to perform such other work as may be necessary to the successful conduct of the survey. He shall prepare a report to the General Assembly before each meeting of the same, setting forth the progress and condition of the survey, together with such other information as the Commission may deem necessary and useful.

Sec. 5. *Be it further enacted*, That the said State Geological Survey shall have for its objects and duties the following:

1. A study of the geological formations of the State, with especial reference to their economic products, including coal, oil, gas, ores, fertilizers, building stones, road-making materials, clays, cement materials, sands, soils, forests, mineral and artesian waters, drainage of swamps, streams, and water powers, and other natural resources.

2. A study of the character, origin, and relations of the soils of the State, with especial reference to their adaptability to particular crops, the maintenance of soil fertility, and the conservation and utilization of supplies of natural fertilizers.

3. A study of the road-making materials of the State, with reference to their character, distribution, and the best methods of utilizing the same.

4. A study of the occurrence and availability of underground water supplies.

5. An investigation of the forests, streams, and water powers of the State, with especial reference to their conservation and development for industrial enterprises.

6. A study of the swamp and other nontillable lands of the State, with reference to their reclamation for agricultural purposes.

7. A study of the physical features of the State, with reference to their bearing upon the occupations, physical welfare, and intellectual pursuits of the people.

8. The preparation of special reports, with necessary illustrations and maps, which shall embrace both general and detailed descriptions of the geology, topography, and natural resources of the State.

9. The preparation of special geologic, topographic, and economic maps to illustrate the structure, relief, and natural resources of the State.

10. The consideration of such other scientific and economic questions as in the judgment of the Commission shall be deemed of value to the people of the State.

Sec. 6. *Be it further enacted*, That the regular and special reports of the State Geological Survey, with proper illustrations and maps, shall be printed and distributed and sold as the Commission shall deem best for the interest of the people of the State and as said Commission may direct, and all moneys obtained by the sale of said reports shall be paid into the State treasury. The said Commission shall cause to be prepared a report to the General Assembly before each meeting of the same, showing the progress and condition of the survey, together with such other information as they may deem necessary and useful, or as the General Assembly may require; *provided, however*, that the Commission shall have the right to print and distribute said reports.

SEC. 7. *Be it further enacted*, That after having served the purposes of the Survey, all materials collected shall be distributed by the Director to the educational institutions of the State in such manner as the Commission may determine to be of advantage to the educational interests of the State; *provided, however*, that if deemed advisable, the Commission may first use such portion as may be necessary to establish a permanent exhibit of the natural resources of the State. On the completion or discontinuance of the State Geological Survey, the Commission shall cause all records, notes, books, reports, charts, maps, manuscripts, instruments, and other equipment and property of the survey to be placed in charge of a suitable custodian to be held subject to final disposition by the General Assembly; *provided, however*, that any field or other equipment which the Commission shall deem it undesirable to preserve may be sold as the Commission may direct and the money turned into the State treasury; and, *provided, further*, that the copies of the reports of the survey left on hand for distribution shall be distributed by the custodian in such manner as shall be for the best interest of the people of the State.

SEC. 8. *Be it further enacted*, That the said Commission is hereby authorized to enter into coöperation with the United States Geological Survey and other scientific bureaus of the Federal and State governments for the prosecution at joint expense of such work in the State as shall be deemed of mutual interest and advantage, and under such conditions as said Commission may deem to be for the best interest of the people of the State.

SEC. 9. *Be it further enacted*, That in order to carry out the provisions of this Act, it shall be lawful for any person employed hereunder to enter and cross all lands within the State; *provided*, that in so doing no damage is done to private property.

SEC. 10. *Be it further enacted*, That for the purpose of carrying out the provisions of this Act, fifteen thousand dollars ($15,000) annually for the years 1910 and 1911, or so much thereof as may be necessary, is hereby appropriated out of any money in the State treasury not otherwise appropriated, and the State Treasurer is hereby authorized to pay out the same on the warrants of the Comptroller upon the presentation of the proper vouchers by the Chairman of said State Geological Commission; *provided*, that the appropriation made herein shall not be available until May 1, 1910.

SEC. 11. *Be it further enacted*, That this Act take effect from and after its passage, the public welfare requiring it.

Passed April 30, 1909.

WM. KINNEY,
*Speaker of the Senate.*

M. HILLSMAN TAYLOR,
*Speaker of the House of Representatives.*

Approved May 1, 1909.

MALCOLM R. PATTERSON,
*Governor.*

## ORGANIZATION OF THE SURVEY.

Under the terms of the bill, the Geological Commission consists of Malcolm R. Patterson, Governor of Tennessee, ex-officio Chairman; John Thompson, State Commissioner of Agriculture; R. A.

Shiflett, Chief Mine Inspector; Brown Ayres, President of the University of Tennessee; J. H. Kirkland, Chancellor of Vanderbilt University; and William B. Hall, Vice Chancellor of the University of the South. The commission held its first meeting on February 7, at which time an organization was perfected and a committee appointed, consisting of President Ayres and Chancellor Kirkland, to canvass the field and recommend a suitable man for the position of State Geologist. As a result of their recommendation, at a meeting held on March 16, the commission elected, as State Geologist, George H. Ashley, of the United States Geological Survey, at the time in charge of work in the eastern coal fields; and as Associate Geologists, Mr. Charles H. Gordon, Professor of Geology at the University of Tennessee, and Mr. L. C. Glenn, Professor of Geology at Vanderbilt University.

On May 1 the Survey began active operations. An office in the Capitol Annex, at Nashville, was made ready and properly equipped with the apparatus necessary for conducting the operations of the Survey. Plans for the first season's work were made, including many for coöperative work with the bureaus of the United States Government at Washington; assistants were selected and work begun.

## PURPOSE OF THE SURVEY.

The purpose of the Survey may be briefly stated: The Geological Survey of Tennessee exists to obtain and publish accurate, definite, and unbiased information on the State's natural resources for the purpose of increasing the wealth and well-being of the State and its citizens through a larger and better use of those resources.

The Survey will be of direct value to the State in several ways: (1) By serving as the State's expert in determining the value, etc., of the State's present large holdings of mineral lands, or of any proposed additional purchases or sales; (2) by supplying the facts and information necessary to intelligent legislation concerning the State's resources; (3) by conserving the State's resources through leading to better methods of obtaining and using them; (4) by helping to bring into the State new capital for investment and the immigration of new citizens; (5) by keeping money in the State through aiding in the establishment of local industries to supply local needs, and by bringing additional money in by enlarging the output of farms, mines, and factories; (6) by leading to added sources of income for the State.

The Survey will be of indirect value to the State through its value to the individual citizens for whose welfare the State exists.

It is of value to the landowner by showing what ores, minerals, rocks, or other resources underlie his land; their depth, volume, character, and value, and to that extent it affects the possible sale value of his land; and, second, by suggesting such use of his land as will make it yield the largest possible return. It is of value to those having capital to invest by supplying unbiased information upon which investments may be made or industries established. It is of value to transportation interests by increasing the volume of both crude and manufactured materials to be moved, through an increased production and an increased demand. It is of value to the purchasing public, which includes most of us, by reducing costs through the production in the State of things that must otherwise be obtained from without, and through increasing the supply of those things. It is of value to the man without work by increasing the demand for labor through the starting of new or enlarging of old industries.

In so far as the Survey may aid in the abating of the smoke nuisance in the cities, in obtaining cheaper light and power through a larger use of our water powers, in aiding and making effective plans for the drainage of the bottom lands, in converting poor farm lands into good farm lands, and in a thousand other ways, it may make it possible for all citizens to have more of the comforts and luxuries of life.

## SCOPE OF WORK.

The Survey is primarily a bureau of information on certain subjects. This implies, first, the collecting of the information; second, the study, systematizing, filing, or preparation of that information; and, third, the supplying of that information.

The subjects on which the Survey is to serve as a bureau of information have already been outlined in Section 5 of the Act under which the Survey is established. They may be grouped as follows:

1. General geology, mineralogy, physics, and chemistry, so far as they relate to the natural resources of this State.
2. Geography of the State.
3. Metals and their ores.
4. Fuels and fertilizers.
5. Structural materials and materials used in the arts.
6. Water and water power.
7. Soils.
8. Reclamation of land.
9. Forests, roads, etc.
10. Miscellaneous materials and products.

The scope of the work may be suggested by running over briefly the subjects just listed, pointing out a few of the lines of information about which experience has shown questions are asked.

*General Geology.*—General geology tells what the rocks are composed of, how they were formed, how they came to be found in their present position, how they have been changed from their first condition, what animals and plants lived at the time they were deposited, the cause and action of earthquakes, mountain building and other geological activities, the history of the earth's surface, of its climate, and a thousand other questions. Sometimes questions are asked about these things for themselves by those desiring to know something of the why and wherefore of the world about them. More often a knowledge of those things is desired because such a knowledge is absolutely essential to any scientific study of the economic products of the earth. It is a matter of common knowledge that the valuable ores, minerals, rocks, fuels, etc., are not uniformly distributed in nature, nor, on the other hand, do they occur with entire irregularity, or as though by mere chance. The experience of men all over the world, when brought together, shows certain relationships between the occurrences of these materials and the occurrence of other materials, or of other conditions and forces. These facts, when all brought together, make up the science of geology.

When, for example, the geologist draws a line around a certain area in the Cumberland Mountains and says, " Within this line there is, or may be, bituminous coal, but outside of it there is none," he bases his statement on a whole volume of " theoretical " information. Thus it implies that he knows the age of the rocks within that line and of all the rocks outside of that line, involving in turn an intimate knowledge of the fossils in these rocks through which their age is determined, and the general meaning and relations of these fossils. But it implies also that he knows the approximate age of every workable bed of coal in the world, and the fact that experience has shown that no workable coal ever has been found in the rocks of the early ages to which the rocks outside of the line he has drawn belong. So, too, when he draws certain belts across and around the State, and says, " If you are interested in zinc, look within the areas indicated, but not outside," he is again basing his statement on the experience of men in mining zinc everywhere and on his knowledge of that experience. To-day there are several thousand geologists, mining engineers, and others who are constantly studying the occurrence and character of the deposits of

ores and other economic minerals and rocks and describing them in hundreds of reports and journals that are printed each year. But there are, in addition, others who devote much of their time to bringing together all of these facts relating to any one subject and drawing therefrom general conclusions based on experience from all over the world. Those general conclusions form the *science* of geology. It is this *science* that the trained geologist must know and must apply if his work is to have any value to the State employing him.

On the other hand, the geologists and mining men, not only in this State, but all over the world, expect that, with the establishment of a Geological Survey in Tennessee, they in turn will receive from that Survey descriptions of all the conditions surrounding the occurrence of the various economic deposits of this State, forming a contribution by the State to the general science of geology. It is, therefore, planned that, in addition to the so-called "theoretical" geology which may accompany the detailed description of ores or other deposits, there may be published from time to time general theoretical papers that bring together all or a large part of the facts in this State along such lines, as: the description of fossils, the structure or "lay" of the rocks, of the origin of various deposits, of the extent and history of any group of rocks, or of any part of the present surface of the State, and of many other similar subjects.

Fortunately, for the rapid prosecution of the present work, a large share of the theoretic geology of the State had already been studied out and published by Troost, Safford, Killebrew, Hayes, Campbell, Keith, David White, Glenn, Ulrich, and others; but in the detailed work to be done by this Survey many other problems will doubtless be met with and will have to be worked out and published as a basis for future investigations.

*Geography.*—The National and State Geological Surveys have always been looked to for the preparation of maps showing the geography of their respective domains, as well as the geology of its rocks and deposits. This work may take on several forms.

One phase of the work is the setting of meridian lines. Just as the geologist, in his travels through the mountains, is constantly being asked to make on the floor of some woodman's porch a north and south line to serve as a noon mark in lieu of a clock, so the Geological Survey is looked to by county surveyors to establish at the county seats accurate meridian lines. It is well known that the compass points not to the north pole, but to the magnetic north pole, and that this magnetic north pole is constantly shifting from year

to year, so that the land line described by the points of the compass in 1850 will not agree with the same points of the compass in 1910. In securing these meridian lines, the State Survey will coöperate with the Coast and Geodetic Survey.

The making of maps will form no small part of the work of the Survey. These will range from small scale maps of the State, showing only the county seats, to large scale detailed maps of small areas, showing all of the roads, trails, houses, streams, the exact shape of the hills and valleys, the location of the mines, quarries, springs, etc. Some of the more detailed maps will show every five-foot change of level in the ground. These maps may be published simply as geographical maps for the use of engineers, surveyors, travelers, landowners, prospectors, or other people; or they may form a basis on which are placed facts about the geology or soils or timber, the roads, water supply, markets, or any one of those things with which the Survey is to deal.

High-grade, plain, geographic maps, showing the topography, are much studied and used, where they exist, for the location of steam and electric railways, of State and county highways, of schools, telegraph and telephone lines, for the laying of water pipes, aqueducts and sewerage systems, for the drainage or irrigation of land, for the position of county and township lines, for selecting the best routes for automobile tours or tramps, in planning maneuvers of the National Guard, in connection with the purchase or sale of land, in gaining exact knowledge of the country, elevation of places, distances and directions between places, and for a multitude of other uses.

In the early days the geologists made their own maps as they went, and in reconnoissance work that is often still necessary; but where detailed work is to be done, requiring detailed topographic maps on which to publish the geologic results, it has been found much more economical to train men for the specific purpose of map making. To obtain such maps, there is required accurate primary and secondary triangulation, traverses, and leveling work. The preparation of such maps is expensive, costing from $4 to $50 per square mile, according to the scale of the map and the character of the country. It has been the practice of most of the States needing such maps to ask the coöperation of the Topographic Branch of the United States Geological Survey, which stands ready within the limits of its funds to make such maps where requested, the State and national governments sharing alike in the cost of the field and office work, but the national government assuming the entire cost

of engraving and printing the maps. At present forty-eight per cent of Tennessee, mostly in the eastern and central parts of the State, has been covered by such mapping, which, in most cases, has been followed by geologic mapping. The early maps, both topographic and geologic, were done rapidly and at small cost. Gradually the grade of such work has been improving, until to-day the United States Government frankly labels later editions of the early maps as "reconnoissance" maps. As the grade of geologic work has risen, it has been found necessary to have better and better topographic maps in order to adequately represent the geologic facts obtained. This has continued until to-day the older topographic maps are entirely inadequate for the representation of geologic facts as obtained by modern methods. The first step in geologic work has, therefore, been the securing of adequate topographic maps.

Fortunately, for the beginning of the new work in Tennessee, a few of such up-to-date topographic maps have been made in this State within the last few years. The recent topographic maps on hand will suffice for the geologic work for the first season or two, but soon active steps must be taken to secure similar good maps of other areas on which the Survey desires to do work. Efforts to secure additional modern topographic maps in Tennessee by the United States Geological Survey will be made.

The present funds of the Geological Survey of Tennessee do not warrant seeking such coöperation, except to a very limited extent. It is hoped in the future that more funds will be available for that specific object.

*Metals and Their Ores.*—In their occurrences the ores of the metals may be divided into two classes: those which occur as original bedded deposits, as the Clinton iron ore of Tennessee, and those which, in a sense, are secondary in their occurrence—that is, have been brought together after the deposition of the containing rocks by segregation, replacement, or otherwise, and occur in veins or other irregularly shaped deposits. Deposits of the first class would be studied very much as are the beds of coal, as described in the following section. In the study of ores of the second class, the Survey will attempt to find out for each of the metals just what formations may contain its ores, to delimit these formations on the map so as to show in just what parts of the State the ores of that metal may or do occur. Then it will try to determine under just what conditions or combinations of conditions the ores do or may occur, and to point out where these conditions exist, using large-scale detailed maps for the purpose. This will involve a study of

the occurrence and origin of all of the known deposits in the State, combined with a knowledge of similar deposits elsewhere. In brief, the aim will be to study the occurrence and origin, the character, extent, and value of all of the known deposits in the State of the metallic ores, first, in order to secure or extend their development; second, to point out just where else they may occur and how they may be recognized; and, third, to tell how they are mined and marketed and to what uses they are or may be put.

*Fuels and Fertilizers.*—Most fuels and fertilizers have, in common, an origin from living forms, either plants or animals, and are deposited in beds often of considerable lateral extent, but of small vertical extent. In many ways the same methods will be followed in tracing phosphates as in tracing coal beds.

Thus, in studying the coal of the State, the Survey will seek to determine the exact limits of the coal field, the series of rocks in that field, the number of coal beds and their position in that series of rocks. Of each bed it will try to determine the average thickness and the variations of thickness from place to place; its analysis, quality, purity, freedom from shale partings, binders, etc.; the character of its roof, floor, etc., as affecting its workability; its distance above or below some conspicuously outcropping rock, so that, by reference to it, the coal bed may be found; the position of the bed in the hill; its probable extent and character in any direction or under any given area; its dip or lay, giving very closely its exact depth at any point; the total tonnage that should be recovered from it; the methods of working, preparing, and marketing the coal; and, finally, the various uses to which it can be put, and especially the more recent advances that have been made in the use of coal. In this work, again, it will be attempted to show on the map accurately the position of each principal coal bed, so that any one with the map in hand could go at once to the position of its outcropping and, by prospecting, determine its presence and local character.

The occurrence of oil does not lend itself so readily to accurate description and forecast. It is a common idea outside of the oil fields that the discovery of oil is the result of hunting over the surface for oil seepage or other visible evidence of oil. It is true that in a few cases the discovery of an oil seepage has been followed by striking oil in a well bored on that evidence; but it is probably also true that not one successful oil well in a thousand has been located on such evidence; while, on the other hand, of all the oil wells drilled on such evidence, probably four-fifths have never paid back the cost of drilling. The successful oil men have always followed

"leads" consisting of lines of structure, water conditions, etc. Oil, like water, runs down hill, and, if it is not associated with water, will accumulate in the lowest part of a fold in the rocks containing it. If it is associated with water, it will, on account of its lightness, tend to rise to the top of the water, which may be along the top of the fold if the rock is full of water, or along the flank of the fold if the rock is only partially saturated. These are a few of the most simple elements of the many that control the occurrence of oil. Within certain broad limits it is possible that oil may be found anywhere in the rocks. Actual experience in any given territory shows that certain beds are more likely to contain oil than others, and under certain conditions of structure, water content, and other factors.

It is the office of the Geological Survey to seek to determine what beds of rock have been shown, by experience, are most likely to contain oil and gas, and under what conditions, and to determine where else those beds occur under those conditions in this State. In this work coöperation with the experts of the Federal Survey will be sought, in order to gain the advantage of their intimate knowledge of the conditions holding in the large developed oil fields of the country.

Phosphate rocks form one of the most valuable assets of this State. Work already done on them has shown that they occur at a few very definite horizons or as secondary deposits made by the weathering of the original deposits and the redeposition of the phosphates. It will be the aim of the Survey to determine accurately just what the limiting conditions are under which the phosphates of this State occur, and then to trace, in detail, the occurrence of these conditions, testing the rocks chemically in the field as the work progresses, and showing the position of the rocks that are found to be phosphatic on detailed maps.

*Structural Materials and Materials Used in the Arts.*—Under this heading will come a large variety of substances, some of them of the first rank in importance, others of only minor importance. Thus it will include marble, limestone, cement rocks, lithographic stone, sandstone, clays, shales, slates, barytes, pyrites, fluor spar, whetstone, glass sand, salt, nitre, silica rock, and many other rocks and minerals of greater or less value. For the present purpose it will suffice to point out some of the lines of study connected with one or two of the substances listed, as, for example, marble and clay rocks.

Marble is a crystallized limestone suitable for fine structural work. The limestones are among the regularly bedded rocks, and their general outcrop has already been mapped. It is probably true that

only a few of the many beds of limestone in this State are ever found in the condition of marble. It will be the purpose of the Survey to determine which of these beds contain marble and to follow their outcrops wherever they occur in the State, examining the rock at every exposure, and showing by detailed maps just where they appear to be of sufficiently high grade to serve as commercial marble. This will include a detailed study of the stratigraphy or position among the rock strata, of all of the known marble deposits, of the fossils by which these particular beds may be recognized, and, afterwards, the detailed tracing and mapping of these beds with close scrutiny for marble.

The clay rocks, from which bricks, tile, terra-cotta, China ware, etc., are made, occur in the earth as regularly deposited beds of clay or shale, or they occur as surface deposits, having been derived from older rocks by decomposition and water transportation. Where they are regularly bedded, it is possible to determine just their stratigraphic position in the rocks. The preliminary work will consist of a study of the developed deposits and the determination of their position, character, etc., and that will then be followed by the detailed tracing, testing, and mapping over the State of the beds that experience or examination shows to contain deposits of commercial character.

The surface deposits are more irregular in their character and disposition, but, aside from those found in the bottoms along streams and rivers, will usually be found associated with certain rocks under certain conditions. The Survey will seek to discover what these associations and conditions are, and then to trace and map wherever these associations and conditions exist.

*Water and Water Power.*—The lines of inquiry in regard to water (aside from rainfall, which is looked after by the National Weather Bureau) deal with run-off of the surface streams, conditions affecting it, and the results under different conditions, as well as possible modifications of the present conditions so as to give better control of the run-off; surface springs, both clear and mineral; underground water supplies, artesian well areas, water-bearing levels or strata; possible sources of water power, with minimum and maximum derivable power, and the problem of its use and transportation; navigation of rivers, water for irrigation, etc.

*Soils.*—After all is said and done, the soil is the earth's great storehouse, furnishing man with his most fundamental necessities —food, clothing, and shelter—and, when properly cared for, continuing to do this from century to century with undiminished gen-

erosity. The soil presents two problems: First, the maintenance or conservation of its physical and chemical substances; second, the increase of its efficiency to the highest possible point. In a large measure, the soil is a factory or place in which raw materials are worked up into finished products. Essentially it is composed of insoluble sand or other substances that do not enter at all into the finished product. Into this factory come the raw materials—some to be stored until needed, and some, as the water, to come and go, except as they are used. The conservation of the soil is mainly an engineering problem, and is considered under the next head. The increase in the efficiency of the soil is a subject of almost unlimited possibilities. It will be the aim of the State Survey, working in conjunction with the other departments already in the field, to make a detailed study of every type of soil in the State; to learn its origin, physical structure, and chemical food contents; to determine to what crops or use it is best adapted in its present condition; to see if its physical condition cannot be improved by some different handling, or by tiling, or in some other manner; to see if it is not lacking in some essential element; to learn from the best farmers now living on that soil what its possibilities are, sometimes noting the experience of farmers from other States on similar soils, or the result of the experiment station studies. These studies having been made largely with the aid of the agencies already in the field, it will be the special province of the Geological Survey to trace, in detail, the extent of each type of soil and to prepare maps of the same. Here again, as elsewhere, arises the necessity for detailed topographic maps, if this work is to be done in sufficient detail to be worth while.

*Conservation and Reclamation of Lands.*—While it must needs be that the hills shall be worn down and carried away to the sea, it is of the uttermost importance that this movement should be as slow as possible. As long as the soil is washed from the hills no faster at any point than the forces of weathering can break up the rock underneath into new soil, there will be no permanent harm done; but when it exceeds that rate, the erosion does damage that is likely to grow worse with time, until land that should have been fruitful for ages becomes barren for all time. Again, if this material washes into the streams faster than it can be carried off, it will serve to produce floods on the bottom lands and to hinder navigation. The problem of the conservation of soils and the prevention of hillside wash will, therefore, form one subject of study by the Survey.

Steps are actively being taken for the reclamation of the bottom

lands of parts of West Tennessee. This is being done by districts organized under the drainage law of 1909. (See Bulletin No. 3, Part C.) These drainage districts are usually organized to cover the portion of any valley lying in one county. This may include the whole valley. Usually it will not. Experience, too often disastrous, has shown the necessity that all drainage work be planned with a knowledge of all of the factors and conditions in the case if the work, when completed, is to be efficient and economical. That it may be both, requires a knowledge of many factors that it may be difficult to get in any one district, or which have already been obtained in some other district. It is, therefore, felt to be the special province of the Geological Survey in aiding in this work to first take such parts of the work as are general in their nature, bringing to the districts such necessary data as that on rainfall, run-off, etc., carrying on observations and experiments where necessary and drawing on the experience of other districts in this and other States where possible.

Again, where there are several drainage districts on the same stream in different counties, it is most desirable that there be some way of coördinating the plan of construction in one district with that in the districts above and below. Otherwise, as has sometimes happened, the construction in one district may follow a different plan from that in the other districts, resulting locally in a worse condition than at first—endless lawsuits, injunctions, etc. It is, therefore, the hope of the Survey to lend its friendly aid, as far as possible, in securing coördination of plans along any one stream.

The work will include not only reclamation of land rendered nontillable because of flooding, but the reclamation of lands from which the soil has been allowed to wash away, or which, for any other reason, has been allowed to become barren and nontillable.

*Forests, Roads, Etc.*—The forest, like the soil, is one of those things that, if properly cared for, will continue itself indefinitely. It is, however, usually treated as one of the things to be exterminated. Over large areas the forest has had to give way to fields and pastures, but there still remain large areas not suited to the cultivation of crops or the raising of cattle. Too often from these areas the native growth of timber has been removed and no effort made to grow a new crop of timber. In the past it has been the general tendency to look upon timber as one might upon rabbits, or bears, or buffaloes—as a part of nature's "wild stuff," to be gotten while it lasts; for when it is gone, it is gone. Of late years there has been a growing appreciation that just as we no longer

think of depending on wild strawberries or wild rice for our supply, so will we not much longer depend on wild timber for our supply. With that appreciation is a growing demand for information about the proper way to cultivate timber; the general conditions of soil, topography, and climate best adapted to timber raising; the kinds of trees best adapted to any given soil, or other factors, etc. As it is at once recognized that the raising of timber will be vastly easier where there is already some of the desired timber on the land, there will be three lines along which inquiry will be made: First, the facts concerning the present supply of timber—its location, kinds, amount, etc.; second, how to conserve the present forests so as to make them a source of future and continuing supply (how many lumbermen now think of selecting and preserving seed trees, as the stockman will preserve and care for his brood stock?) ; third, a reforestation of areas better adapted to the raising of trees than of anything else and that never should have been deforested. These are the lines along which the Survey plans to gather and publish information.

What the railroads have been in the building up of the country at large, good roads may be in the building up of smaller divisions of the country. There are three factors of cost of farm products or lumber—cost of production, of transportation, of distribution. Every dollar saved in any of these three points is a dollar earned. If it costs the farmer twenty cents a bushel to haul his wheat to market over a poor road and ten cents over a good road, and he raises one thousand bushels, the poor road has cost him just one hundred dollars for the moving of that one crop alone.

The Geological Survey hopes to be able to aid in the building of good roads in at least three ways: First, through the detailed topographic maps, which will aid in showing the amount of rise or fall a road will have to have in going from any one point to another, and then showing where it can be placed so as to keep within the maximum grade decided on, for as the strength of a chain is determined by its weakest link, so the hauling efficiency of a road is measured by its steepest grade; second, it may help by locating, testing, and mapping materials suitable for the building of roads; third, in connection with the last in coöperation with the Good Roads Division of the Federal Agricultural Department, it may point out and illustrate methods of road building, use of materials, etc., in addition to what it may do by publication of road maps and general information about roads.

## WORK OF THE SURVEY.

The work of the Survey will fall under the following heads:

1. Field work.
2. Office work.
3. Laboratory work.
4. Exhibit and educational work.
5. Publication.

*Field Work.*—The field work will vary in character and methods in accordance with the objects sought. While the great bulk of the work will consist of detailed studies and mapping, in most cases this will have to be preceded by preliminary studies. These preliminary studies will be made at the points at which any given mineral resource is or has been developed. Such work will consist of personal visits to the various active plants by some member of the Survey, the examination and measurement of the deposits to determine their origin, age, relationships, mode of occurrence, size, quantity, quality, character, methods of extraction, the process of smelting or recovery, etc. These reports will usually be accompanied by sections and maps. The facts obtained will be of value in showing the present condition of the industry involved, the kind of material used, how it occurs, etc. These facts will also be used and be necessary for determining the condition of occurrence on which the future detailed studies and mapping will be based.

In some cases this work will consist of excursions to examine some locality at which it has been reported there occurs some ore or mineral of wide interest or value; or the work may be a reconnoissance study of all of the known occurrences of some resource, as of coal, oil, or phosphate.

The detailed work will be of two kinds—areal work and the tracing and study of some one resource. In many cases the areal work will be done in connection with the study of the principal resource of that area. In the areal work a set of traverse lines is run all over the area, some of them following the streams and gullies, some the roads, some the hillsides, following along the outcropping of a bed of rock or mineral, others filling in the spaces between, as it may be necessary in order to complete the mapping or to examine some prospect or mine. As these traverses are run a record is made, by means of a double system of notes on field maps and in notebooks, of every geologic fact, including a graphic description of every outcrop of rock, its thickness, color, grain, bedding, dip, etc.; if possible, its stratigraphic position is determined

or noted, if known; fossils are collected wherever necessary; samples and specimens are collected for analysis, study, or exhibit. The notes are made in such a way as to show accurately the horizontal and vertical relations of all of the facts collected. In this way, no matter how fragmentary the facts may be, they are fitted at once into their proper place, and, as the work progresses, data lacking at one point may be supplied from some other point. Gradually it becomes possible to fill in the lacking information to a greater or less degree, just as it becomes possible to fill in a picture of a partially set up puzzle, even though most of the pieces are still lacking, for, wherever these traverses may go, all are so tied together that the relations of any fact obtained on one becomes obvious to all of the facts on any other line.

If beds or deposits of known or suspected economic importance are encountered, they are examined in more minute detail following certain more or less well-defined lines of procedure; if desirable or necessary, efforts are made to secure better exposure of some economic deposits. Wherever possible, the information obtained directly by the geologist in the field is supplemented by reports of drilling and prospecting made by mining and prospecting companies, by observations made by those residing in the district, or by any other data obtainable.

In the detailed study of any selected economic resource, all of the conditions of its occurrences, its character, quantity, etc., are determined by the preliminary study. The main work will include the detailed tracing of the occurrence of these conditions wherever the general conditions make it possible for them to exist.

From what has just been said and from what was said under "Scope of Work," it is evident that all of the detailed mapping will require detailed topographic maps. It is not enough to say that such and such a coal bed outcrops within a mile to the east of such and such a town, or that it underlies between one hundred thousand and two hundred thousand acres. Its outcrop should be shown within at least a few hundred feet horizontally and a very few (twenty) feet vertically (generally much nearer); the area it underlies should be known within at least a few hundred acres. It will not always be possible to secure such accurate results, but results as close or closer will always be aimed at.

To do detailed work in the oil and gas, phosphates, soils, cement work, clays, and most other materials, will require the same detailed topographic base maps as in working the coal or iron, if the results obtained in the field are to be adequately represented.

It is hardly necessary to outline all of the various methods adopted in the field work where various results are to be secured. The methods used by the several Federal bureaus, which will cooperate in topographic mapping, soil mapping, oil and gas work, forest mapping, etc., have been described in detail in publications issued by these several bureaus, and in many cases will be given in connection with reports on their work to be published by this Survey in the future. Different methods from these described will have to be used in the study of road materials or underground waters or water powers or of many other such subjects.

*Office Work.*—The office work will consist, first, of the correspondence and other work necessary in the planning and carrying on of the work of the Survey; second, in the identification of specimens sent in or brought in; third, in supplying information about any of the subjects with which the Survey is concerned, especially as to the location of deposits of desired materials, etc.; fourth, the collection and tabulation of information about mines, drillings, etc., partly to meet the demand under the third clause and partly in preparation for future field work or publication; fifth, the working up of the material obtained in the field and the preparation of the reports; sixth, the study of the literature relating to the natural resources of the State, and the preparation of preliminary circulars of information and of a bibliography of the literature.

A few words of further explanation may be made of some of the lines of work just listed. One of the first lines taken up is that mentioned last. In the course of the prosecution of previous National, State, and private geologic and other surveys and studies, a large amount of valuable information has already been gathered. This is scattered in a great many publications of many kinds, some of which are out of print, many of which can be obtained only with difficulty, and in most cases the information on any one subject or about any one locality is scattered through a dozen or a score of publications.

As a preliminary to the reports on the detailed studies to be made by the Survey, many of which cannot be ready for some years, preliminary circulars of information will be prepared as rapidly as possible, drawn from all sources of information available at the time. This information must necessarily be gathered for the use of the Survey, and, if published in brief, summarized form, will serve for answering inquiries until the reports of the detailed work become available.

The office work of preparing the field material for publication

will vary greatly according to the character of the work. Where the subject of the study lies entirely at the surface, the report may consist simply of a transcript of the field notes properly arranged, condensed, and edited, accompanied usually with a map, and the time involved is usually short as compared with the time required for the field work. More often the notes themselves are used as the basis for certain general conclusions, and these must first be reached, often involving complicated computations, reaching conclusions that must then be interpreted in terms of the map, etc. In still other cases dealing with materials almost or entirely underground, as with the coal, oil, gas, and other such resources, the data is apt to be mostly of such indirect character, and often so incomplete that the working up of such data is a long, slow job, involving endless plotting out of well records, the projecting of surface dips to the depth of the deposit being studied, with all of the necessary calculations to allow for the differences in the dip due to the changing thickness in the intervening beds; the constant application of the law of probabilities, based on the known conditions occurring elsewhere in developed territory. Where doubt exists as to the identity of any bed outcropping at the surface, it may be necessary to make a series of possible assumptions and carry the full set of calculations through with each to determine the bed's most probable identity and the probable depth, etc., of the subject of study. This statement is given in explanation of the seeming long delay that experience has shown is apt to ensue between the field work and the appearance of the report wherever these underground deposits are concerned.

The collection and tabulating of data to-day forms no small part of the work of the office. The success of a given piece of field work often depends on having copies of records of wells or prospects. If the collection of these is left until the field work is to be done, too often it is impossible to get all of the records. Experience has shown that the best way is to get them when they are available. Having gotten them, they are of no use unless properly classified and filed, so as to be available whenever wanted. The same thing is true of a large amount of data about the mines and quarries, of analyses, of the results of prospecting, and of information received through correspondence or from office callers. The Survey will employ the usual business methods in filing and caring for this material.

While the published reports and circulars will be depended on in the main in answering inquiries, the Survey always stands ready

to supplement the reports with any personal explanation that may be necessary. It is intended that in any case the report will give all of the information possessed by the Survey (except confidential data); but the writer realizes that, in applying the conclusions of a report to any particular locality, it is not always easy to see or understand just what the result of the application will be locally.

The identification of specimens brought or sent to the Survey has always been recognized as one of its legitimate functions. While it is true that it is only rarely that specimens so received by the Survey have any wide interest or value, and that a large share of the specimens prove to contain only mica or pyrite (fool's gold) or other substance that is of no value in the form in which it occurs in the specimen, yet it is as much the function of the Survey to prevent the useless expenditure of money on noncommercial projects as to encourage its expenditure on other projects.

The correspondence and other work necessary to the planning and carrying on of the work of the Survey may be judged by the success or otherwise of the work itself.

*Laboratory Work.*—In accordance with the general plan of not duplicating plants in existence or work already being done, the Survey does not plan to establish elaborate chemical or physical laboratories at this time. On the other hand, it plans to make use, as far as it may, of the laboratories already in existence, such as those of the State Chemist, the State Agricultural Experimental Station, the new Federal Bureau of Mines, and the several laboratories of the Federal Agricultural Department. In this way it will be possible not only to avoid the large expense of equipping full laboratories, but in many cases it may be possible to secure coöperation in the laboratory work so as to obtain a division of the expense.

In most cases it will be possible to secure such coöperative laboratory work only where the work being done is of interest to the coöperating bureau or department. There will doubtless arise from time to time many minor chemical questions which will make it desirable that the Survey be equipped to make simple qualitative tests in the prosecution of its work, and it will be so equipped. In another part of this bulletin a statement is made of the Survey's policy in regard to doing analytical work for private parties.

In addition to the chemical analysis of the various materials constituting the resources of the State, there are to-day many experiments being carried on looking to the better utilization or preparation of the mineral resources of the State. The Technologic Branch of the Federal Geological Survey, which now forms part of the new

National Bureau of Mines, has for several years been carrying on extensive experiments in the better utilization of coal and other substances, and there are to-day a number of experimental laboratories, such as that connected with the University of Illinois, that are doing work of a very high grade. While this Survey does not anticipate undertaking any such work at this time, it will plan to keep in close touch with results of such work being carried on elsewhere, and to call attention to such results through the medium of its reports wherever such results have a direct bearing on the utilization of the resources of this State. In addition to that work, it will attempt to follow the practical application of any of those suggested better methods as they may be applied in this State, or of any other experiments that are being carried on within the State by the producers or large consumers.

Success in the business world to-day is spelled in good management and good methods. The first is mainly a matter for the individual to work out for himself, but the second point comes as a matter of experience based on experiment. In the mining, metallurgy, or preparation and utilization of nature's resources, there is much to be learned.

To take the case of coal again. In many districts but little more than one-half of the coal in the bed is obtained by mining; in others ninety-five per cent of the coal is gotten. It has often happened that by some change in the methods of preparing the coal for market, a gain of five per cent or ten per cent may be made in the amount of marketable coal obtained, or in the price obtainable for the coal as a whole without the mining of an additional ton. The ordinary steam engine does not obtain more than five per cent to ten per cent of the power available in the coal. Power equipments are now being built that obtain from twenty per cent to thirty per cent or more of the coal's power from the same amount of coal by first converting the coal into producer gas and the use of that in a gas engine. Indeed, it seems possible to look forward to a day when all of the power being used in at least Eastern and Middle Tennessee that is not derived from water power will be generated at the mines in the coal fields and transmitted electrically to where it is to be used. The smokeless combustion of fuel is another item of large interest to the cities.

*Exhibit and Educational Work.*—This work will consist, first, of the collection of specimens showing the various ores, minerals, rocks, and fossils occurring in the State, with specimens illustrating the several steps in the processes of refining, smelting, screening,

or otherwise preparing for market; second, of the preparation of a State exhibit properly labeled and displayed; third, of the preparation of suitable exhibits of the State's resources at the expositions that are held from time to time; fourth, of the preparation of school collections from the surplus material collected by the Survey to be distributed to such schools of the State as give courses along the lines of the Survey's work; fifth, the preparation of "popular" bulletins in untechnical language of the origin and mode of occurrence of the deposits constituting the mineral resources of the State, of the history of the mountain ranges of East Tennessee, of the Cumberland Plateau, of the basin of Middle Tennessee, of the Mississippi Valley, of the State's caves and other objects of special interest, of the nature and development of soils, of the simple principles of erosion and deposition, etc.; sixth, of the giving of talks and lectures by the State Geologist and other members of the Survey on the State's resources or geology; seventh, of the preparation of special magazine articles on Tennessee and its resources for outside popular and technical magazines, calling attention to the opportunities the State offers for business enterprises or profitable employment, the beauty of its scenery, its advantages as a place of residence, its educational, climatic, and other advantages.

*Publications.*—The results of the Survey's work are to be published as bulletins, to be issued as rapidly as they are prepared, and numbered serially. In the case of some of the first bulletins, which will be largely a review and gathering together of our present knowledge of the geology and resources of the State, the bulletin may consist of several distinct papers, and a small edition of the individual papers will be issued as fast as ready to supply the demand for such information. The individual papers will be treated as preliminary papers or as "circulars of information."

As the cost of publishing the bulletins must come from the appropriation for the Survey, the editions will be kept as small as possible, and every effort made to distribute them with care in order that they may fall into the hands of those having a real interest in the subjects treated. For that reason no widespread distribution of the bulletins will be made as they appear. They will be sent free to libraries, educational institutions, the press, State officials, foreign officials connected with geology, mining, agriculture, and forestry, and to such persons as are in active coöperation with the department or have rendered tangible service in the work in hand. Notices will be sent to such as by inquiry or otherwise have expressed an interest in the particular subject treated, and they and

any other persons interested may obtain copies of the bulletins upon request by inclosing necessary postage.

In many States it has been the experience that long after the edition of a report has been exhausted there continue to come requests for that report, often from persons having large interests in the matter treated of, or who are considering local investments, and the fact that no copies are to be had may result in a distinct loss to the State. To meet that difficulty, five hundred copies of each edition will be reserved for sale at the cost of publication. This small supply should serve to meet the need of late comers, who, if they have a real interest in the matter of the report, can hardly object to the small cost necessary to obtain the information they desire. In accordance with the bill establishing the Survey, all funds obtained in this way are returned directly to the State Treasury.

As many of the Survey's bulletins will be small, and as it is often difficult in a large library to properly care for small bulletins, the plan will be tried of reserving a part of each bulletin unbound until the end of the year and then to bind all these parts together into a library edition. Under this plan the distribution of bulletins to the libraries will not be made until the end of the year.

In subject-matter, the bulletins will fall into five classes:

*A. General Information.*

This will include bulletins that contain such information as would be desired by a citizen having only a general interest in the subject in question, or by people outside of the State making general inquiries. It will include bulletins on broad subjects involving the State as a whole, and general and preliminary papers on such large subjects as coal or iron (in which the detailed descriptions will fill many bulletins), where they will be used until the study of any given area is completed.

*B. Detailed or Local Descriptions.*

This will include the bulletins giving the results of detailed studies of a given deposit or of a limited area, as of a county. The bulletins on the several counties will be included under this head. As requests are mainly for information relating to some subject rather than to some county, as such, the detailed studies of the counties will be taken up in connection with the study of the principal resources they contain. Preliminary papers on the various counties may be issued to meet immediate requirements.

*C. Technological Bulletins.*

These bulletins will deal not with the geologic descriptions of deposits, but with the technique of their use or mining, or other mat-

ters of that kind, such as the smokeless combustion of coal, the electrical transmission of water power, the prevention of hillside wash, etc.

*D. Educational and Scientific Bulletins.*

These include bulletins describing the minerals or rocks of the State, its stratigraphy, paleontology, physiography, etc.

*E. Progress Reports.*

This will include the biennial administrative report of the director of the Survey to the State Legislature, reports of partial results of long-continued investigations, etc.

## COÖPERATION.

In formulating the policy of the Survey, it has been the idea of the State Geologist that the desire of the people of Tennessee was not so much to build up a strong State Survey as to secure certain results with the least possible delay and at the smallest possible cost. The experience of many of the States has shown that by coöperating with the Federal bureaus, which are thoroughly equipped with the necessary instruments, with specialists who have been trained by years of work, ready to take the field at once, that any piece of work can be done with much less cost to the State than for the State to attempt to do that work for itself.

Accordingly coöperative agreements have been entered into with several branches of the Federal Geological Survey and with several of the bureaus of the Agricultural Department, in addition to coöperative arrangements with several of the other departments of this State. Under these coöperative agreements, as a rule, the work is done under the direction of a government expert, the expense and the results being shared equally. In many cases the Federal Government pays salaries and the State Government pays the field expenses, which, as a rule, will not amount to as much as the salaries. In some cases, as in the coöperation with the United States Geological Survey, two types of reports are prepared—an economic report, which goes to the State, and a scientific report, which is published by the national government. As a rule, the State Survey determines the amount and grade of work to be done, and where it is to be done, provided such proposed work will fit into the general plans of the Federal bureaus concerned. So many of the States have entered into coöperative agreements with the bureaus of the Federal departments that the funds of some of these Federal bureaus go largely into coöperative work, so that

States not coöperating have very little work done in them by these bureaus.

Some of the advantages to the State with these coöperative agreements may be cited: In the first place, the amounts of such work done in this State and made available to its citizens is nearly twice as large as the State Geological Survey could do alone; in the second place, the State reaps the advantage of having the work done by trained specialists without having to build up or train a corps of high-salaried men for possibly small amounts of work in each of their lines; in the third place, the national bureaus usually have facilities for engraving and printing the maps showing the results of the surveys, and transfers of such maps may be obtained by the State for its own use at a small fraction of what the engraving costs; in the fourth place, many of the geologic and other features occurring in this State are parts of large provinces extending over many adjacent States, and the members of the Federal bureaus bring to the work in this State a knowledge of the conditions in other States in which the same formation is found.

There are, of course, many phases of work in which the State Survey has a vital interest, in which the Federal bureaus do not have an interest, and in which they will not, therefore, coöperate. In many respects their interest is more of a general nature than a purely economic, whereas the State Survey is primarily economic and only secondarily deals with matters of general interest. The State Survey is, in a sense, an advertising agency for the State's resources, and in that line naturally the Federal surveys can take no part. There are many types of reports that must be gotten out by the State Survey in pursuance of the particular objects it has in view, in which it cannot coöperate with the Federal surveys.

In general, in planning coöperative work, the attempt is made to secure such coöperation for the most detailed and expensive lines of work, while reconnoissance work and other studies dealing with purely local matters will be taken up by the State Survey.

For the first season coöperative agreements have been made with the Geologic and Topographic Branches of the United States Geological Survey, and with the Bureau of Soils, the Public Roads Division, and Drainage Investigations of the Federal Department of Agriculture, and tentative plans have been made with several other bureaus and departments for coöperative work in the future. As a rule, the Federal bureaus pay salaries and the State pays expenses, so that its money does not go out of the State. Where the work is largely of purely local interest, as in the drainage surveys, a large part of the expense is borne by the local interests.

## RELATIONS TO THE PUBLIC.

In common with all of the national and State Surveys, the Geological Survey of Tennessee has certain rules and regulations which prohibit the director or any member of the Survey from having any personal or private interest in any of the lands or mineral wealth of a region under survey or from executing any surveys or examinations for private parties or corporations in this State. This is absolutely necessary if the reports of the Survey are to be kept free from any suspicion of bias or willful misrepresentation.

Except where the results will be of large public interest, the Survey will not undertake the examination of property for private parties, as that work properly belongs to the mining geologist or mining engineer.

Rocks or minerals properly packed and sent, postpaid, to the director will be examined without cost, providing an assay or chemical analysis is not necessary. Exception to the latter rule may be made if the director believes the specimen to contain valuable mineral, the determination of which will be of value to the work of the Survey and an aid in the study of the resources of the State. When requested, names of reliable parties will be given, who may be employed to furnish assays or chemical analyses. The Survey reserves the right to publish, at any time, any assay or analysis made at its expense.

Two of the regulations are of such character that they had best be quoted in full:

> "Members of the survey are expressly forbidden to give individuals or corporations, in advance of publication, the results arrived at in the course of geological examination in a district or area. They are at liberty, however, to communicate orally to the owner or manager of a mineral property, during the progress of its investigation, such information with regard to the geology of that property as may be of value to him in its development; but written statements must be avoided, lest they be used for promoting or unduly enhancing values."

> "Information of a confidential character, such as mine maps, drill records, statistics of production, etc., supplied by private parties or corporations, must be carefully guarded and used in the preparation of reports for publication strictly in accordance with the conditions stipulated by the persons furnishing it."

In general, in planning the work for each season, the plans are largely influenced by the volume and character of inquiries for information that have been received, modified by the existence of adequate base maps or other limiting factors. As already explained, it will not pay to attempt to do detailed geological work in a region

where no adequate base map exists, and before work of that character can be done in such a region, such an adequate base map must be prepared. It will, however, often be possible to make reconnoissance surveys in regions which have not as yet been topographically mapped. At the present time, with the small number of up-to-date base maps available, that factor, more than any other, will determine where the detailed work is to be done. In the beginning, however, a large amount of reconnoissance work will be desirable in order to prepare preliminary general bulletins.

It may often happen that residents of a district believe that district to contain deposits of economic value, and under these circumstances the director would be very glad to have his attention called to the matter, and, subject to the limitations imposed by the facilities of the Survey, would gladly comply with requests for such examination, provided a sufficient number of people are interested in the matter to justify the expenditure of the State appropriation and provided that such requests are made early enough in the year so that advance plans may be made for the doing of such work at the time that plans are made for the season's work.

# BULLETIN 1-B

1-B

STATE OF TENNESSEE—STATE GEOLOGICAL SURVEY

GEORGE H. ASHLEY, State Geologist

# BIBLIOGRAPHY

OF

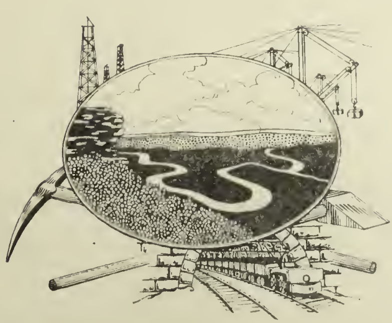
# Tennessee Geology, Soils, Drainage, Forestry, Etc.

WITH SUBJECT INDEX

BY

ELIZABETH COCKRILL

EXTRACT (B) FROM BULLETIN No. 1, "GEOLOGICAL WORK IN TENNESSEE."



NASHVILLE
FOLK-KEELIN PRINTING COMPANY
1911

# CONTENTS

# INTRODUCTION.

The following bibliography was prepared by Miss Cockrill, first as a card catalogue and cross reference index for the use of the Survey, and then for publication for general use.

As is readily seen, a large amount of geologic work has already been done in Tennessee. While many of these reports and papers are out of print or can be obtained only with difficulty, on the other hand, many of them can be obtained for the asking or at a relatively small cost.

It is the purpose of the present State Survey to prepare a series of bulletins summarizing all that is now known of the different mineral resources, and the different counties, and in many cases, these summaries will cover all of the facts presented in the earlier reports, and to that extent will, for practical purposes, entirely superseded those reports; but no attempt to duplicate the detailed earlier reports will be made until such time as the Survey's own detailed work shall have covered that area, resource or problem.

For example, the Columbia folio by the U. S. Geological Survey is a beautiful piece of work and mapping, describing the phosphate rocks occurring in that region, the rocks in which the phosphates occur, their probable origin, their general distribution, their general chemical character, but no details are given. In the progress of its detailed study of the phosphate rocks, the State Survey will ultimately hope to publish, not only detailed maps of the phosphate deposits, but detailed descriptions of all the deposits, giving, as far as possible, detailed sections, description of extent, analyses, etc. But meanwhile many people may want to refer to the Columbia folio if they know of its existence. So, too, the Columbia folio describes some interesting embayment deposits. Ultimately the State Survey hopes to trace those deposits to their natural limits, but it may be some years before that can be done, and in the meanwhile many people would be interested in the facts brought out even in as limited an area as that covered by the Columbia folio.

Therefore, it has been felt that it would be a distinct service to publish a list of the reports and papers that have been written on the geology, soils, drainage and forestry of Tennessee. The bibliography makes no pretense to being complete, especially in the cross indexing (as many of the earlier papers, especially, are not contained in the State Geologist's private library, which, for the time being, must serve the needs of the new Survey).

But it was felt it would be of more value to bring the list out without delay, rather than to wait the several years that are usually necessary to search out the few additional titles to make it complete.

In preparing the bibliography, Miss Cockrill has made use of the various bibliographies on geology issued by the U. S. Geological Survey, and has supplemented that by lists kindly furnished by the several bureaus of the Agricultural Department, Coast and Geodetic Survey, etc., and by such other titles as could be learned of from the people in the State. In this work she has received a large amount of assistance from Professor Glenn,

who has gone through all of the geological library of Vanderbilt University, including Professor Safford's books, so that including a large number of titles from the reports of the Chief of Engineers, State Board of Health, and similar publications, he added nearly a thousand titles to those previously obtained. Mr. Nelson has aided in preparing the index and in the proof reading.

The government reports are usually to be obtained by request from the heads of the several bureaus, thus letters for such reports should be addressed to: The Director, U. S. Geological Survey, Washington, D. C.; The Superintendent of the Coast and Geodetic Survey, Washington, D. C.; The Director, Office of Public Roads, Agricultural Department, Washington, D. C.; Chief of Bureau of Soils, Department of Agriculture, Washington, D. C.; Chief Forester, Forest Service, Washington, D. C., etc. A few of the publications are sale publications, such as the topographic atlas sheets and the folios of the U. S. Geological Survey. In these cases, the charges made are simply to cover the cost of printing and binding. The topographic atlas sheets can be obtained at a cost of five cents each, and the folios for twenty-five cents each (stamps not accepted). In some cases the supply of these publications for distribution for the several bureaus will be found to have been exhausted. Application should then be made to the Superintendent of Documents, Washington, D. C., from whom they may be purchased at the cost of publication. If the supply of that official is exhausted, they can only be obtained from second hand book dealers, or from people to whom they were previously sent. Many of these publications can be consulted at the libraries, as most of the libraries receive full sets of the government publications.

Nashville. GEORGE H. ASHLEY.

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See **McLendon** (W. E.) and **Zappone** (C. R., Jr.)

# INDEX

## A

**Cannon County.**

Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
McMinnville folio, Keith, 16.
Oil and gas developments in Tennessee, Munn.

**Carroll County.**

Clays, Crider; Nelson; Eckel, 3.
Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Terrestrial magnetism, Bauer, 2; Faris, 3.
Underground waters, Glenn, 6.

**Carter County.**

A trip to Roane Mountain, Chickering, 1.
Cranberry folio, Keith, 13.
Fluorite and barite in Tennessee, Watson, 2.
Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Iron ore deposits of Cranberry district, Keith, 14.
Notes on Roane Mountain, Chickering, 2.
Report on the Tennessee River, Walden's Ridge and Carter County ore fields, Roberts, (J. D.).
Report of the Tennessee River, Walden's Ridge iron ores, Guild, 1.
Roane Mountain, Kenworthy.
Roane Mountain folio, Keith, 8.
Terrestrial magnetism, Bauer, 1; Faris, 3.

**Caves.**

Caves and cave life, Kingsley.
Wonder Cave of Tennessee, Payne.

**Cement.**

An investigation of some Tennessee cement materials, Lund.
Cement resources of the Cumberland Gap district, Tennessee-Virginia, Eckel, 4.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Knoxville folio, Keith, 5.
Loudon folio, Keith, 6.
Maynardville folio, Keith, 16.
Morristown folio, Keith, 17.
Portland cement resources of Tennessee, Ulrich, 1.
Statistical reports, Shiflett, 5 and 9.

**Central Basin.**

The Central Basin of Tennessee, Kennedy.

**Cheatham County.**

Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Oil and gas developments in Tennessee, Munn.
Terrestrial magnetism, Faris, 3.

**Chester County.**

Terrestrial magnetism, Faris, 3.
Underground waters, Glenn, 6.

**Chromite.**

Ashville folio, Keith, 11.

**Claiborne County.**

Cement resources of the Cumberland Gap district, Tennessee-Virginia, Eckel, 4.
Cumberland coal field and its creators, Ashley, 1.
Cumberland Gap coal field of Kentucky and Tennessee, Ashley, 2.
Geology and mineral resources of part of the Cumberland Gap coal field, Kentucky, Ashley and Glenn.
Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Lead and zinc deposits of the Virginia-Tennessee region, Watson, 1.
Maynardville folio, Keith, 16.
Mineral resources of the upper Cumberland Valley of southeastern Kentucky and southwestern Virginia, McCreath and D'Invilliers.
Mining in the Cumberland Gap coal field, Pultz.
Report of work done in the division of chemisrty and physics mainly during the fiscal year, 1888-89, Clarke (F. W.), 1.
Southern Appalachian coal field, Hayes, 23.
Tennessee marbles, Keith, 15.
Terrestrial magnetism, Bauer, 1.
Zinc belt of Claiborne and Union Counties, Tennessee, Clarke (W. C.), 1.

**Clay County.**

Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Oil and gas developments in Tennessee, Munn.
Standingstone folio, Campbell, 1.

**Clay.**

Asheville folio, Keith, 7.
Clay deposits of Tennessee, Brown (L. P.), 4.
Clay of the United States, east of Mississippi River, Ries.

East Tennessee—Continued.

An essay on the medical topography of East Tennessee, Ramsey.
Beobachtungen uber Erz-Gange und das Gang-Gebirge von Nord-Carolina und den angrenzenden Staaten, Diffenbach.
East Tennessee copper mines, Gilbert.
Extent and value of East Tennessee minerals, Cowlam.
Geology of Tennessee, Safford, 22.
Geological and mineralogical account of the mining district in the states of Georgia — — —, and East Tennessee, Peck.
Geological notes in western Virginia, North Carolina and eastern Tennessee, Britton.
Iron-ore deposits of the Cranberry district, North Carolina-Tennessee, Keith, 14.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Mineral and agricultural resources of the portion of Tennessee along the Cincinnati Southern railroad, Killebrew, 3.
Mineral resources along the line of the East Tennessee-Virginia and Georgia division of the So. Ry., Brewer (Wm. M.), 2.
Notes on the samples of iron ore collected in East Tennessee, Willis, 1 and 3.
Recent zinc mining in East Tennessee, Keith, 10.
Remarks on the mineralogy and geology of the northwestern part of the State of Virginia and eastern part of Tennessee, Kain.
Remarks on the changes which take place in the structure and composition of mineral veins, Whitney, 1.
Report of the geology of northeastern Alabama and adjacent portions of Georgia and Tennessee, Hayes, 3.
Report on the Embree Iron Furnace properties, Lesley, 4.
Some drift hematite deposits in East Tennessee, Nichols.
Southern red hematite as an ingredient of metallic paint, Burchard, 1.
Southern magnetite and magnetic separation, Chase.
Tennessee iron ores, Maxwell.
Tennessee marbles, Keith, 15.
The Cretaceous and Tertiary peneplains of eastern Tennessee, Dodge.
The medical topography of the valley of East Tennessee, Boyd (S. B.).

East Tennessee—Continued.

The mineral and agricultural resources of East Tennessee, Knoxville Board of Trade.
Zinc deposits of Tennessee, Gordon, 3.
Zinc in East Tennessee, Clarke (W. C.), 2.

Economic Geology.

Economic geology of the Bristol and Big Stone Gap section of Tennessee and Virginia, Boyd (C. R.), 2.
Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Resources of Tennessee, Anon., 1.

Elk River.

Final report upon survey of Elk River, Kingman, 16.
Improvement of Elk River, Kingman, 6 and 21; Knight, 11.
Preliminary examination of Elk River, Newcomer, 16; King, 3.
Survey of Elk River, Kingman, 22.

Emory River.

Examination of Powell's, Clinch and Emory rivers, McFarland (Walter), 3.
Preliminary examination of Emory River, Robert (Henry M.), 3.
Survey of Emory River, Kingman, 30.

## F

Fayette County.

Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Terrestrial magnetism, Faris, 1.
The Middleton formation of Tennessee, Safford, 33.

Fentress County.

Fentress County, Tennessee, coal and timber, Clarke (Jas. N.).
Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Oil and gas developments of Tennessee, Munn.
Report of State Geologist, Safford, 31.
Standingstone folio, Campbell, 1.
Terrestrial magnetism, Bauer, 1.
Wartburg folio, Keith, 4.

Fertilizer.

Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
See Phosphate.

**Flint.**

Geology of Tennessee, Safford, 22.

**Fluorite.**

Fluorite and barite in Tennessee, Watson, 2.
Fluorspar in Tennessee, Hayden.
Statistical reports, Shiflett, 1, 2, 3, 4, 5, 6, 7, 8 and 9.
The Nashville Division, Southern Railway, 4.

**Forests.**

A brief description of the forests of Tennessee, Anon., 6.
Chestnut oak in the southern Appalachians, Foster and Ashe.
Conservative lumbering at Sewanee, Tenn., Foley, 1.
Forest conditions and possibilities in Tennessee, Ramage.
Forests and forest conditions in the southern Appalachians, Ayres and Ashe, 2.
Forests of Tennessee, their extent, character and distribution, Sudworth and Killebrew.
Forestry and stream flow, Harts, 1.
Geology of Tennessee, Safford, 22.
Hardwood bottom lands in two southern states, Anon., 5.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Management of second growth in the southern Appalachians, Zon.
Message from the President of the United States, Roosevelt.
Necessity of preserving the forests of Monteagle, Summey.
Necessity of preserving the forests of Tennessee, and legislation necessary for that purpose, Killebrew, 12.
On the timber line of high mountains, Meehan.
Preservation of the Appalachian forests in a national park, Battle (R. H.).
President's opening address, Killebrew, 11.
Relation between geology and forests, Manning.
Relation of forests to manufacturing industries of Tennessee, Powell, 1.
Relation between geology of Tennessee to manufacturing industry of the state, Powell, 2.
Resources of Tennessee, Anon., 1.
Some native trees for parks and yards, Hinds, 1.
State forestry association for Tennessee (organization), Anon., 2.

**Forests**—Continued.

Sylviculture in relation to city streets, parks and private grounds, Kelley.
Tennessee forests, Anon., 3.
The southern Appalachian forests, Ayres and Ashe, 1.
The influence of forests on streams, Glenn, 11.
Timber in Tennessee, Killebrew and Safford, 1.
Waning hardwood supply and the Appalachian forests, Hall (Wm. L.).
What can the state do in the matter of forestry, Anon., 4.
White oak in the southern Appalachians, Greeley and Ashe.
Working plan for southern hardwoods and its results, Foley, 2.

**Forked Deer River.**

Examination of Forked Deer River, Suter.
Examination of North Fork of Forked Deer River, Benyaurd, 4.
Examination of South Fork of Forked Deer River, Benyaurd, 5.
Improvement of Forked Deer River, Newcomer, 7 and 14; Willard, 2, 3, 5, 7 and 10; Adams, 2, 5, 7 and 10; Biddle, 1, 7 and 10; Kingman, 24.
Improvement of South Fork of Forked Deer River, Bergland, 1 and 3; Miller (A. M.), 1 and 3.
Improvement of Obion and Forked Deer Rivers, Barden, 2; Harts, 13, 21 and 29; Sears, 4.
Preliminary examination of Obion and Forked Deer Rivers, Sears, 1.
Preliminary examination of North Fork of Forked Deer River, Willard, 11.
Survey of North Forked Deer River, Biddle, 3.
Survey of Forked Deer River, Biddle, 5.

**Franklin County.**

Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Oil and gas developments of Tennessee, Munn.
Sewanee folio, Hayes, 10.
Stevenson folio, Hayes, 13.
The topography, geology and water supply of Sewanee, Safford, 49.

**French Broad River.**

Examination of French Broad River from the Henderson County line, McFarland (Walter), 2.

**General Geology**—Continued.

Report of a geological reconnoissance of the lands, free-hold and lease-hold of the Cumberland Basin Petroleum and Mining Company, Ely.

Report of a geological examination made on certain lands and mines, Owen (Richard).

Report of the State Geologist, Safford, 36.

Second biennial report on geology of Tennessee, Safford, 4.

Sketch of the geology of Tennessee, with description of its minerals and ores, Currey, 1.

Sketch of the geology of the United States, Rogers, (H. D.), 1.

Soil and geological map of Tennessee, Nashville, Chattanooga & St. Louis Railway.

Sur le gisement de l'or en Californie, Marcou, 2.

Tennessee, Safford, 13.

The economic and agricultural geology of the State of Tennessee, Safford, 47.

The geology of Tennessee, Safford, 40.

The topography, geology and water supply of Sewanee, Safford, 49.

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Report of the Department of Geology, Minerals, Mines and Mining, Safford, 42.

Uber die Geologie der Vereinigten Staaten und der enhlishcheb Provinzen von Nord-Amerika, Marcou, 3.

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**Geography.**

Boundaries of (Tennessee), Gannett, 1.

Dictionary of altitudes (in Tennessee), Gannett, 2.

Dictionary of geographic positions (in Tennessee), Gannett, 3.

Editorial review of Safford's second biennial report, Currey, 4.

Geographical positions determined approximately in West Virginia, Kentucky, Tennessee, U. S. Coast Survey.

Geographical (sic) survey of Tennessee, Troost, 13.

Northern boundary of Tennessee, Garrett.

On the results of spirit leveling of precision between Corinth, Miss., and Memphis, Tenn., Schott, 1.

**Geography**—Continued.

Report of Dr. J. M. Safford, State Geologist, Safford, 30.

Report of State engineer on surveys for railways and highways, Lea, (A. M.).

Report on the southern boundary line of Tennessee, Foster, (——).

Results of spirit leveling of precision between Okolona, Miss., and Odin, Ill., Schott, 2.

Results of primary triangulation (in Tennessee), Gannett, 4.

Results of primary triangulation and primary traverse, Gannett, 5.

**Gibson County.**

Clays of West Tennessee, Nelson.

Drainage of the river bottoms and swamp lands of West Tennessee, Cooper.

Geology of Tennessee, Safford, 22.

Introduction to the Resources of Tennessee, Killebrew and Safford, 2.

Preliminary report upon drainage of the lands overflowed, Morgan and McCrory.

Stoneware and brick clays of western Tennessee and northwestern Mississipii, Eckel, 3.

Terrestrial magnetism, Faris, 3.

Underground water resources of Tennessee, Glenn, 6.

**Giles County.**

Geology of Tennessee, Safford, 22.

Introduction to the Resources of Tennessee, Killebrew and Safford, 2.

Oil and gas developments in Tennessee, Munn.

Soil survey of Giles County, Tenn., Ayrs and Gray.

**Gold.**

Cranberry folio, Keith, 22.

Geology of Tennessee, Safford, 22.

Introduction to the Resources of Tennessee, Killebrew and Safford, 2.

Knoxville folio, Keith, 5.

**Grainger County.**

Geology of Tennessee, Safford, 22.

Introduction to the Resources of Tennessee, Killebrew and Safford, 2.

Maynardville folio, Keith, 16.

Moristown folio, Keith, 17.

Soil survey of Grainger County, Tenn., McLendon and Lyman.

Tennessee marbles, Keith, 15.

Terrestrial magnetism, Bauer, 1.

**Granite.**

Geology of Tennessee, Safford, 22.

**James County**—Continued.

Ringgold folio, Hayes, 7.
Southern red hematite as ingredient of metallic paint, Burchard, 1.

**Jefferson County.**

Fluorite and barite in Tennessee, Watson, 2.
Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Lead and zinc deposits of the Virginia-Tennessee region, Watson, 1.
Maynardville folio, Keith, 16.
Morristown folio, Keith, 17.
Terrestrial magnetism, Bauer, 1.
Zinc mining in Tennessee, Osgood.

**Johnson County.**

Cranberry folio, Keith, 13.
Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Terrestrial magnetism, Bauer, 1.

## K.

**Knox County.**

Briceville folio, Keith, 7.
Building stone, Merrill, 1.
Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Knoxville folio, Keith, 5.
Lead and zinc deposits of the Virginia-Tennessee region, Watson, 1.
Loudon folio, Keith, 6.
Maynardville folio, Keith, 16.
Tennessee marbles, Keith, 15.
Terrestrial magnetism, Faris, 1; Bauer, 1.

**Kraurite.**

Kraurite and Cacoxene in Tennessee, Troost, 15.

## L.

**Lake County.**

A second visit to North America, Lyell.
Clays of West Tennesee, Nelson.
Drainage of the river bottoms and swamp lands of West Tennessee, Cooper.
Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Oil and gas developments in Tennessee, Munn.
Terrestrial magnetism, Faris, 1.
Underground waters, Glenn, 6.

**Lauderdale County.**

Clays of West Tennessee, Nelson.
Drainage of the river bottoms and swamp lands of West Tennessee, Cooper.
Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Terrestrial magnetism, Faris, 2.
The upland geological formations of Obion, Dyer, Lauderdale—Safford, 53.
Underground waters, Glenn, 6.

**Lawrence County.**

Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Oil and gas developments in Tennessee, Munn.
Silurian and Devonian limestones of western Tennessee, Foerste, 4.
Soil survey of Lawrence County, Tenn., Mooney and Ayrs, 2.
Western iron belt of Tennessee, Killebrew, 8.

**Lead.**

Briceville folio, Keith, 7.
Cleveland folio, Hayes, 14.
Cranbery folio, Keith, 13.
Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Lead and zinc deposits of Virginia-Tennessee region, Watson, 1.
Maynardville folio, Keith, 16.
Mineral resources along the line of the East Tennessee, Virginia and Georgia division of Southern Railway, Brewer (Wm. M.), 2.
Morristown folio, Keith, 17.
Southern Railway territory, Southern Railway, 1.
Statistical reports, Shiflet, 1, 2, 3, 4, 5, 6, 7, 8 and 9.
The Nashville division, Southern Railway, 4.

**Lewis County.**

Columbia folio, Hayes and Ulrich.
Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Silurian and Devonian limestones of western Tennessee, Foerste, 4.
Tennesse phosphates, Hayes 12 and 17.
Terrestrial magnetism, Faris, 1.

**Lignite.**

Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
The lignitic stage, Harris, 2.

**Obion County.**

A second visit to North America, (on earthquakes), Lyell.
Clays of West Tennessee, Nelson.
Drainage of river bottoms and swamp lands of West Tennessee, Cooper.
Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Terrestrial magnetism, Faris, 3.
The upland geological formations of Obion, Safford, 53.
Underground water resources, Glenn, 6.

**Obion River.**

Drainage of the river bottoms and swamp lands of West Tennessee, Cooper.
Drainage problems in Tennessee, Ashley, 6.
Examination of Obion River, Benyaird, 3.
Improvemnt of Obion River, Adams, 1, 4, 7 and 9; Biddle, 4, 6, 9, 13 and 22; Kingman, 23.
Improvement of Obion and Forked Deer Rivers, Barden, 2; Harts, 13, 21 and 29; Newcomer, 7 and 14; Sears, 4.
Preliminary examination of Obion and Forked Deer Rivers, Sears, 1.
Preliminary examination of Obion River, Barlow, 9.
Survey of North Forked Deer River from Dyersburg to main stream, and thence to Obion River, Biddle, 3.
Survey of North Forked Deer River from Dyersburg, Tennessee, to its junction with the Obion River, Biddle, 5.
Underground water resources, Glenn, 6.

**Oil and Gas.**

Cumberland Gap coal field, Ashley 2 and 3.
Geography of petroleum, geology of petroleum, Wrigley.
Geology and mineral resources of part of Cumberland Gap, Ashley and Glenn.
Geology of Tennessee, Safford, 22.
Geological report on the petroleum lands and leases of Capt. L. H. Thickstun, Harper (D.), 2.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Mineral Oil, Newberry.

**Oil and Gas**—Continued.

Mineral resources of the United State Williams (Albert, Jr.), 1, 2 and 3; Day (D. T.), 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22 and 23.
Notes on the geological position of petroleum reservoirs in southern Kentucky and Tennessee, Safford, 9.
Oil and gas developments in Tennessee, Munn.
Oil boom in Tenessee, Schmits.
Oil region of Tennessee, with some account of its other resources and capabilities, Killebrew, 4.
Report of a geological reconnoissance of the lands, freehold and leasehold of the Cumberland Basin Petroleum and Mining Company, Ely.
Report of the Bureau of Agriculture, Statistics and Mines, Killebrew, 16.
Report on lands of the Jackson Mining and Petroleum Company, Safford, 51.
Statistical reports, Shiflett, 4, 5, 6, 7, 8 and 9.
Well records, Lines.

**Onyx.**

Resources of East Tennessee, Southern Railway, 2.

**Ordovician.**

Cincinnati group in Western Tennessee, between Tennessee River and the Central Basin, Foerste, 5.
Variation in the thickness of the subdivisions of the Ordivician of Indiana, Foerste, 6.

**Overton County.**

Geology of Tennessee, Safford, 22.
Introduction to the Resources of Tennessee, Killebrew and Safford, 2.
Soil survey of Overton County, Ayrs and Hill.
Standingstone folio, Campbell, 1.

## P.

**Paleontology.**

A critical summary of Troost's unpublished manuscript on the crinoids of Tennessee, Wood (Elvira).
Association of the gasteropod genus Cuclora with phosphate of lime deposits, Miller (Arthur M.).
Camden chert of Tennessee and its Lower Oriksany fauna, Safford and Schuchert.
(Catalogue of) Paleozoic sponges of North America, Head (W. R.).

**Stratigraphy**—Continued.

Pre-Cambrian geology of North America, Van Hise.

Remarks on the thickness and identity of the Calciferous formation, Walcott, 3.

*Carboniferous.*

Carboniferous of the Appalachian Basin, Stevenson, 2.

*Cretaceous.*

Correlation papers, Cretaceous, White (C. A.).

On the Cretaceous and superior formations of western Tennessee, Safford, 8.

The Cretaceous and Tertiary peneplains of eastern Tenessee, Dodge.

*Devonian.*

Correlation papers, Devonian and Carboniferous, Williams.

Lower Carboniferous of the Appalachian Basin, Stevenson, 1.

On Marcellus and Hamilton of the south and west, Rogers (H. D.), 3.

Silurian ad Devonian limestones of west Tennessee, Foerste, 4.

*Ordovician.*

A correlation of the lower Silurain horizons of Tennessee, with those of New York, Ulrich, 2.

Cincinnati group in western Tennessee, Foerste, 5.

Lower Silurian deposits of the upper Mississippi, Winchell (N. H.) and Ulrich.

On the parallelism of the Lower Silurian groups of Middle Tennessee with those of New York, Safford, 2.

Preliminary notes on Cincinnatian fossils, Foerste, 8.

Silurian basin of Middle Tennessee, Safford, 1.

Utica slate and related formations, Walcott, 1.

Variation in thickness of subdivisions of Ordivician, Foerste, 6.

*Paleozoic.*

Paleozoic intraformational conglomerates, Walcott, 7.

*Quaternary.*

Drift of southern States, Hilgard (E. W.), 6.

On the geological history of the Gulf of Mexico, Hilgard (S. P.).

Quaternary formation of the State of Mississippi, Hilgard (E. W.), 3.

Remarks on the formations comprised under the term "Orange sand", McGee, 6.

The Columbia formation, McGee, 5.

**Stratigraphy**—Continued.

The loess of Mississippi valley, Hilgard (E. W.), 5.

*Silurian.*

Die Silurische Fauna des westlichen Tennessee, Roemer.

Late Niagaran strata of West Tennessee, Pate and Bassler.

Silurain and Devonian limestones of Tennessee and Kentucky, Foerste, 1.

Silurian and Devonian limestones of western Tennessee, Foerste, 4.

Upper Silurian beds of West Tennessee, Safford, 7.

Use of the term Linden and Clifton limestones, Foerste, 2 and 3.

*Tertiary.*

Age and origin of the LaFayette formation, Hilgard (E. W.), 8.

Appomattox formation on the Mississippi embayment, McGee, 1.

Contributions to the Tertiary geology and paleontology of the United States, Heilprin, 2.

Lafayette formation, McGee, 4.

Mode of deposition of the LaFayette formation, Hilgard (E. W.), 7.

Orange sand, Lagrange and Appomattox, Hilgard (E. W.), 2.

Remarks on the formation comprised under the term "Orange sand", McGee, 6.

Southern extension of the Appomattox formation, McGee, 2.

Tertiary geology of eastern and southern United States, Heilprin, 1.

The lignitic stage, Harris, 2.

The midway stage, Harris, 1.

**Structural Geology.**

Folded faults of the southern Appalachians, Keith, 12.

Fossiliferous sandstone dikes in the Eocene of Tennessee and Kentucky, Glenn, 2.

Geology of Chilhowee Mountain in Tennessee, Keith, 2.

Message from the President of the United States, Roosevelt.

Notes on the age and structure of the several mountain axes in the neighborhood of the Cumberland Gap, Shaler.

Note on a fine upthrow fault at Embreeville Furnace, Lesley, 2.

On a cross anticlinal in the coal measure of eastern Tennessee, Lesley, 3.

On the faults of southern Virginia, Lesley, 1.

# Classified Key to Index

# Publications of the State Geological Survey of Tennessee

The following list shows the publications issued by the State Geological Survey or in preparation at the time this bulletin goes to press, March, 1911. Except for five hundred copies of each publication (which are reserved for sale at the cost of printing), the bulletins will be sent free on request, accompanied by stamps, made to the State Geologist, Capitol Annex, Nashville, Tenn.

Bulletin Nos. 1-A, 2-A, 2-E, 2-G and 3, issued.

Bulletin No. 1.—Geological work in Tennessee (Parts A and B issued).
- A. The establishment, purpose, object and methods of the State Geological Survey; by Geo. H. Ashley; 33 pages, issued July, 1910; postage, 2 cents.
- B. Bibliography of Tennessee and related subjects; by Elizabeth Cockrill.
- C. History of Geological work in Tennessee; by L. C. Glenn (in preparation).

Bulletin No. 2.—Preliminary papers on the Mineral Resources of Tennessee; by Geo. H. Ashley and others. (Parts A, E and G issued.)
- A. Outline introduction to the Mineral Resources of Tennessee; by Geo. H. Ashley; issued September 10, 1910; postage, 2 cents.
- B. The coal fields of Tennessee; by Geo. H. Ashley (in preparation).
- C. The iron ores of Tennessee; by R. P. Jarvis (in prepartion).
- D. The marble of East Tennessee; by C. H. Gordon (in preparation).
- E. Oil and gas development in Tennessee; by M. J. Munn (issued). postage, 2 cents.
- F. The phosphate deposits of Tennessee; by Lucius P. Brown (in preparation).
- G. Zinc Mining in Tennessee; by S. W. Osgood (issued); postage, 1 cent.
- H. Preliminary Geological map of Tennessee, (in preparation).

Bulletin No. 3.—Drainage Reclamation in Tennessee; 74 pages; issued July, 1910; postage, 3 cents.
- A. Drainage Problems in Tennessee; by Geo. H. Ashley; pp. 1-15; postage, 1 cent.
- B. Drainage of Rivers in Gibson County, Tennessee; by A. E. Morgan and S. H. McCrory; pp. 17-43; postage, 1 cent.
- C. The Drainage Law of Tennessee; pp. 45-74; postage, 1 cent.

Bulletin No. 4.—Administrative Report of the State Geologist for 1910.

Bulletin No. 5.—Clay deposits of West Tennessee; by Wilbur A. Nelson (in press).

Bulletin No. 6.—Road Building in Tennessee; by Geo. H. Ashley (in preparation).

Bulletin No. 7.—Water Resources of Tennessee; by L. C. Glenn (in preparation).

Bulletin No. 8.—Economic Geology of the Dayton-Pikeville Region; by W. C. Phalen (in preparation).

Bulletin No. 9.—Studies of the Forests of Tennessee.
- A. An investigation of the forest conditions in Tennessee; by R. Clifford Hall (in preparation).
- B. A study of the growth of the second growth hardwoods; by W. W. Ashe (in preparation).

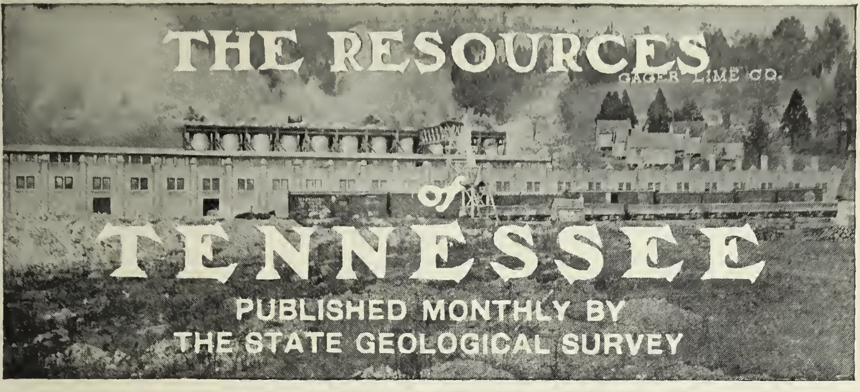
Bulletin No. 10.—The marbles of East Tennessee, illustrated with colored plates; by C. H. Gordon (in preparation).

Bulletin No. 11.—Preliminary report on copper deposits of Polk County; by W. H. Emmons (in preparation).

Bulletin No. 12.—The undeveloped small water powers of Tennessee; by J. A. Switzer and Geo. H. Ashley (in press).

# NOTE

It was the original plan of the Survey to publish the material on *The History of Geological Work in Tennessee,* as Bulletin 1-C; but from a change of plans, it was published as the leading article in Volume II, No. 5, of *The Resources of Tennessee,* under the title, *The Growth of Our Knowledge of Tennessee Geology.* This number of *The Resources of Tennessee,* is herewith inserted, in order to complete the publications as originally outlined.




VOL. 2. NO. 5 NASHVILLE MAY, 1912

Improvement of navigable streams in Tennessee. Lock and Dam on the Cumberland River, near Nashville.

## IN THIS ISSUE

# THE RESOURCES OF TENNESSEE

*A Magazine Devoted to the Description, Conservation and Development of the Resources of Tennessee*

PUBLISHED MONTHLY AT NASHVILLE BY

THE GEOLOGICAL SURVEY OF TENNESSEE

A. H. PURDUE, State Geologist

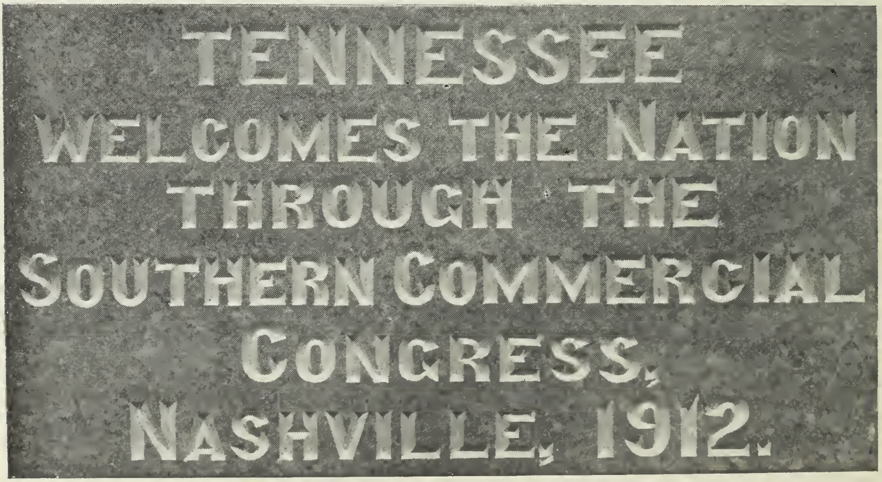
Entered as second-class matter July 14, 1911, at the Postoffice at Nashville, Tenn., under the act of July 16, 1894.

## Presentation of Marble Slab to Southern Commercial Congress by State Geologist.

*Mr. Chairman, Ladies and Gentlemen:*

The Southern Commercial Congress has for its prime object the development and conservation of the sources of wealth in a large section of our country. It already has taken rank with the great organizations of the United States—I might say of the world—and ultimately its influence will be felt by every man, woman and child in the entire South.

The two main sources of wealth are the soil on one hand and the mines and quarries on the other. So it is entirely fitting that the State of Tennessee, through its Geological Survey, should present to this Congress, as representative of its mineral resources, this slab of marble taken from our quarries, upon which the gavel of such historic significance, graciously to be presented by the Ladies Hermitage Association, shall fall in calling this Congress to order during its sessions in our capital city. The slab has upon it the following inscription:




It is with the greatest pleasure that I present it.

# The Growth of Our Knowledge of Tennessee Geology.

BY L. C. GLENN.

## Aboriginal Period.

Some of our earliest Tennessee history is intimately connected with and really in large measure determined by our geology, and the knowledge of this geology, or rather of its results, long antedates the arrival of the white man.

A slight fault in the Ordovician rocks at Nashville has for untold ages permitted salt water to find its way to the surface and form a spring that has been known for ages both to the wild animals and to the aborigines. It is probable that the discovery of this salt spring or lick was first made by wild animals, for it was known to them some few thousand years ago when the mastodon lived in this region, since its bones, tusks and teeth have been found in the muck and mire of the spring. After the mastodon had become extinct the spring continued to be a great gathering place for the buffalo, the elk, and the deer, as well as for the animals—including man—that come to prey upon them.

The aborigines were probably thus first attracted to the spot. Later they learned how to obtain salt by boiling the water, for fragments of the large, crude, flat-bottomed earthenware pans in which they made salt are found mingled with the bones of living and extinct animals is the mud about the spring. Whether the early aborigines who built the mounds and buried their dead in stone cysts were the first to boil salt here can not now be known, though it would seem probable, as they once lived in large numbers in and near where Nashville is now situated.

## Period of Exploration, Settlement and Early Travel.

It is certain that when in 1714 the first French trader pushed up the Cumberland, he found this salt lick frequented by vast herds of buffalo and other animals that came for salt, and by the Indians, who came for the game. The advantages of such a spot for a trading post were recognized at once by the French, and one was established and maintained until the English came in 1780, and settled at the French Lick, as it was then called. Out of this settlement Nashville has grown. It may fairly

Note—For references to the articles mentioned in this review of Tennessee Geology, the reader should consult Miss Cockrill's Bibliography of Tennessee Geology. Full citations here are confined chiefly to articles not contained in that bibliography. Acknowledgments and thanks are due Dr. G. P. Merrill and the Smithsonian Institution for the use of cuts of Maclure, Owen, Lesley, Lesquereux, Hilgard, Winchell, Bradley and Chamberlin.

be said that this bit of early geological knowledge, on the part, first, of the wild animals, then the Indians, and later the French and English, was the determining factor in the location of what was to be the future capital of our State.

This matter of obtaining salt was equally vital to the early settlers, and as the various other salt licks of the region were discovered by the hunters, they either became centers for settlement, or were frequented on hunting expeditions. As early as 1789 public measures were taken to encourage salt making in Middle Tennessee, as all the salt then used was brought from St. Genevieve, Mo., and cost sixteen dollars or more per hundred weight.

In East Tennessee the settlement that began in 1768 soon led to the discovery of various minerals, among which was iron ore, and before the end of the eighteenth century iron-making had been begun in the eastern part of the state, though specific references to the earliest forges in that section are difficult to obtain.

Goodspeed* says that there was a bloomary in Washington County in 1790, another at Elizabethton built about 1795, and at Wagner's on Roane Creek, the same year. He says the forge on Camp Creek, Greene County, the Mossy Creek forge and the Dumpling forge were all built in 1797. The first furnace in West Tennessee was probably the Cumberland furnace in Dickson County, built between 1790 and 1795, and another early one was the Brown furnace in Montgomery County built about 1802.

Andrew Michaux,† who was probably the first scientific exporer of the state, mentions in 1795 an iron works or forge near Mossy Creek in Jefferson County. Michaux crossed the state from North Carolina to Nashville, thence went north into Kentucky, and next year returned to North Carolina, and although primarily interested in botany, has left in his journal occasional notes that show that he was also interested in geology. He mentions a mineral occurring in East Tennessee that, when powdered, would dye cotton red, showing that the dyestone properties of the Clinton red hematite had already been recognized there. He describes the rocks about Nashville as some clayey, and others limestone, as lying horizontal and abounding in marine petrifactions. He also mentions the occurrence at Nashville of petrifactions of land and fresh water shells, and so must have seen, while here, some of the beds of Pleistocene shells found on the old flood plain terraces of the Cumberland River in and about the city.

*A History of Tennessee*, pp. 260-261, Goodspeed Pub. Co., Nashville, 1886.

†Sargent, C. S., Portions of the Journal of Andre Michaux, Botanist, written during his travels in the United States and Canada, 1785 to 1796. Amer. Philos. Soc., Proc., Vol. 36, pp. 1-145, 1889. Also portions translated into English in Thwaites, R. G.: Travels west of the Alleghenies, Cleveland Ohio, 1904.

In 1802 F. A. Michaux,* a son of Andrew Michaux, and also a naturalist, made a journey from Lexington, Ky., to Nashville, and then went east to Knoxville, Greeneville and Jonesboro, and thence crossed the mountains to Morganton, N. C. He describes the greater part of Tennessee west of the Cumberland Mountains, as reposing on horizontal beds of chalky substance; says salt springs are abundant in the state, but that none had yet been worked; speaks of finding a black shale with a white efflorescence on it on Roaring River—evidently the Chattanooga black shale—mentions caves from which an earth used in dyeing cloth is obtained, and finally tells us that lime was then made at Knoxville and shipped by boat to New Orleans.

The above mentioned reference to cave earth by the younger Michaux is followed by several other references to the same subject in the next few years, showing that the people of the state were thus early exploring caves in search of niter for the manufacture of gunpowder. A great impetus to such search was given by the war of 1812, which caused a greatly increased demand for gunpowder, and at the same time shut off the usual foreign supply of niter necessary for its manufacture. During this war many caves in Tennessee were ransacked for cave earth from which niter was obtained. Two Nashville firms alone are said to have bought $150,000 worth of niter in 1813. After peace had been made with Great Britain the niter industry languished, and although scattering references are made to it for a few years, it was probably soon abandoned. While the industry lasted, the largest and more accessible caves at least were pretty thoroughly worked. In this working, many bones, both of man and of living and extinct animals, were found, nearly all of which were thrown aside and destroyed. One writer, for instance, mentions seeing in one place about a hundred human skulls from skeletons that had been unearthed by the workers in the cave. In a cave in White County the skeleton of a Megalonyx was found back some two miles from the entrance. Fortunately part of this or another skeleton from the same cave was saved, and some of it is in the Academy of Natural Sciences in Philadelphia, and the rest is at Vanderbilt University.

In 1809, William Maclure published his *Observations on the Geology of the United States*, with a colored geological map of the region east of the Mississippi. This was the first attempt to construct such a map of America, and although he is said to have crossed and recrossed the Alleghenies no less than fifty times in his travels in quest of geological information, neither the map nor the report evince much actual acquaintance with Tennessee. It seems probable that he has been into East Tennessee, and he may have passed westward to Nashville, but he almost

*Michaux, F. A., Travels to the west of the Allegheny Mountains, London, 1805.

certainly knew nothing of the section of the state between the Tennessee and the Mississippi rivers. A second edition of his Observations was published in 1817, with a revised map. There are very few direct statements as to Tennessee, except for the part of the State east of the Cumberland Mountains, and the Tennessee part of the revised map is less accurate than the original. His work, however, for several decades influenced the views of others who wrote on Tennessee geology, and so deserves a brief word.

WILLIAM MACLURE

From the North Carolina line westward half way across the valley of East Tennessee the rocks are represented in both editions of the Maclure map as being fossiliferous and lying tilted more or less on edge, and they are regarded as Transition in age. The western half of the Great Valley is left uncolored in the older map, save for a narrow belt just east of Knoxville, represented as containing salt and gypsum. The author may either have been undecided as to the age of these rocks or uncertain as to the position of the boundary line between the rocks to the east and those to the west. In the revised map of 1817 the rocks in the western half of the Great Valley of East Tennessee, although tilted on edge, are regarded as belonging to the same division as the rocks of the Cumberland Plateau, and of Middle and West Tennessee. The chief characteristic possessed in common by these rocks, and the sole one on which they were grouped together as a unit, was that they were all flat-lying. To them the name Secondary was applied. In the original map these Secondary rocks extend from the eastern edge of the Cumberland Plateau westward to include a very narrow strip west of the Tennessee River as it crosses the State northward, then a blank belt occurs, west of which alluvium is represented as covering the western half of West Tennessee. In the revised map all of West Tennessee is represented as of the same age as the Cumberland Plateau and Middle Tennessee.

Although evidently not acquainted with West Tennessee, Maclure makes an interesting guess in his revised work in saying that since the Tennessee River heads far back in the Primitive area of western North Carolina, it will be apt to bring down much sand and gravel, and that in

consequence the State of Tennessee may contain a greater area of gravel ridges and sand beds than the other states of the Mississippi basin, whose chief rivers—like the Ohio, for example—flow from areas of shale and limestone, and so bring down only fine alluvium. One has but to examine such counties as Wayne, Hardin, Perry and others in that section of the State to recognize the presence of coarse deposits whose existence Maclure thus shrewdly guessed.

When one considers the time and circumstances, it is not to be wondered that this first attempt at a geological map should contain so much error. It is unfortunate, however, that Tennessee should have been probably the least known of all the states to Maclure, and that the influence of his errors should have been perpetuated so long. Even Doctor Troost did not wholly escape this influence.

Following Maclure, Nuttall seems to have been the next scientific traveller to have left notes of journeys through our state. Although he was chiefly a botanist and ornithologist, yet he also made observations on geology during his travels. He made a number of journeys into the interior of the Mississippi Valley between 1809 and 1820, and during these journeys was in Tennessee one or more times. He mentions the limestone just east of Cumberland Gap and the great amount of niter found in caves in the Cumberland Mountain region of Tennessee. Following Maclure, he ascribes the limestone to what was then known as the great Secondary formation, and mentions lignite as having been found in the soft deposits of the Mississippi Valley.

On December 16, 1811, the first shock of the New Madrid earthquake occurred, and succeeding shocks, some of considerable intensity, were felt for some years, while occasional lighter shocks continue down until the present day. This earthquake caused much fissuring and disturbance of the surface, and numerous changes of level occured in the northwestern corner of Tennessee. In one of the sunken areas water gathered and formed Reelfoot Lake. The region was sparsely inhabited at that time and contemporary accounts are not as numerous or as full as would be desirable. One of the best early accounts is by Mitchill,[1] while others are given by Dow,[2] Foster,[3] Flint,[4] Bringier,[5] Haywood,[6] Audubon,[7] LeSieur,[8] and others—a number of these are quoted by Safford,[9] Broadhead,[10] Fuller,[11] McGee,[12] and Shepard.[13] Fuller has, in 1912, published a very detained account of the earthquake.[14]

1. Mitchill, S. L., *Lit and Philos. Soc. N. Y., Trans.*, Vol. 1, pp. 281-307, 1815.
2. Dow, Lorenzo, *Works,* Cincinnati, 1850, p. 344.
3. Foster, J. W., *The Mississippi Valley*, Chicago and London, 1869.
4. Flint, Timothy, *Recollections of the Last Ten Years,* Boston, 1826, pp. 222-228.
5. Bringier, L., *Amer. Jour. Sci.,* 1st Ser., Vol. 3, pp. 20-22, 1821.

Along with Jameson's translation of *Cuvier's Theory of the Earth,* there was published in 1818 *S. L. Mitchill's Observations on the Geology of North America.* He held the fanciful belief that the Great Lakes are the remnants of former great seas that once covered much of the interior of the continent, but that escaped by breaking through their barriers. He regarded Cumberland Gap as one of the avenues of escape, but thought that the widest gap in the confining barrier was between the Cumberland Mountains and the highlands of southern Missouri. He describes Pleistocene fossils from practically all of the surrounding states, but gives none from Tennessee. There is in fact no evidence in his work that he had ever been in our State, or had any specific knowledge as to its geology.

In 1818 the Rev. Elias Cornelius, in going from Boston to New Orleans, crossed East Tennessee, and gave the results of his observations on its geology in the first volume of the *American Journal of Science.* He describes the limestone east of the Cumberland Mountains as inclined, and says some near Knoxville looks like variegated marble, but had not yet been tested. The strata of the Cumberland Plateau and Middle Tennessee are described as horizontal, and the Cumberlands are recognized as being table mountains, structurally, and composed of both limestone and sandstone strata. He describes the magnificent views from Lookout Mountain, mentions "the Suck," the caves and the making of niter, and refers to the common minerals described by Kain in the same volume of the Journal.

The writer thus alluded to was John H. Kain, of Tennessee. Although his article occupies but eight pages in the *American Journal of Science,* it contains much more information than any preceding article on the geology of the state, and may in fact, be regarded as the first distinctly geological description of any part of the state. He describes the ridge and valley topography of East Tennessee, and criticises Maclure's map for not extending the Transition, or tilted rock, area northwestward to include all of the Valley of East Tennessee. He describes the limestone, clay, slate and gypsum, and mentions the baryta of Sevier County and the lead of Grainger and Davidson counties. He says immense quanti-

6. Haywood, John, *Nat. and Aborig. Hist. Tenn.,* 1823.
7. Audubon, J. J., See *Audubon and His Journals,* Vol 2, pp. 234-237, *Scribners,* 1897.
8. LeSieur, G., See *Switzler's Hist. of Mo.* or *Campbell's Gazetteer of Mo.*
9. Safford, J. M., *Geol. of Tenn.,* pp. 123-125, 1869.
10. Broadhead, G. C., *Amer. Geologist,* Vol. 30, pp. 76-87, 1902.
11. Fuller, M. L., *Science,* n. s., Vol. 21, pp. 748-749, 1905.
12. McGee, W J, *Amer. Geologist,* Vol. 30, pp. 200-201, 1902.
13. Shepard, E. M., *Jour. Geol.* Vol. 13, pp. 45-62, 1905.
14. Fuller, M. L., *U. S. Geol. Surv. Bull.,* 496, 1912.

ties of coal are reported to exist in the Cumberland Mountains, and that a bed of excellent quality was then worked near Knoxville, but, because of the abundance of wood, was used only in forges. Gold and silver were reported to exist, but he regards the accounts as vague and uncertain and not to be credited. A red iron ore was then used to manufacture paint near Knoxville, and numerous caves in the Cumberland and other mountains were very productive of niter.

Kain thus gives us in 1819 our first definite information as to the use of coal and mineral paint in the state, and it would seem likely that niter making had not entirely ceased at that time. The reported finds of gold were no doubt fictitious, as Kain believed, for Troost speaks of being present on Coca Creek in 1830, when the first authentic discovery of gold was made in the state. The silver was of course a myth.

In clearness, directness, and brevity, this article of Kain's stands out in such contrast to all that had previously been written on Tennessee geology that it is to be regretted that he did not write more. We know nothing further of him, save that he was a Tennessean and probably lived in upper East Tennessee.

Four years later, in 1823, John Haywood published his curious *Natural and Aboriginal History of Tennessee*. He gives for the natural history of the state a quaint mixture of fact and fancy. The prominent physical features of the State are ascribed to the sculpturing power of the Noachian deluge. In Middle Tennessee a great basin was thus scooped out, which was filled with the water of the Cumberland River and formed a great lake whose level rose until it overflowed the rim on the northwest side and gradually deepened its outlet until the lake was drained. This fanciful idea of a lake having once filled the central basin of Tennessee has persisted in some minds down to the present day. On a par with the above idea was his credulity regarding fossils and freaks of nature. He describes petrified snakes and mushrooms near Nashville, petrified turkey eggs near Sparta, with the yolk clearly visible, and adds petrified hickory nuts and walnuts and petrified horse hoofs and tracks; while in West Tennessee he believed there was abundant evidence of former volcanic activity. He adds a description of milk sickness, and ascribes it to poisonous mineral matters in the soil—an explanation of this puzzling disease that is probably as good—or as worthless—as any that our best physicians today can offer.

Yet in spite of his fancies he gives us certain geological facts worthy of note. He describes the flat or tilted position of the rocks in various parts of the State and mentions the marine shells in the rocks of East and Middle Tennnessee and the huge oyster shells just west of the Tennessee River, while there and farther west there was petrified wood. Mention is made of caves and their nitrous earths; of marbles in East

Tennessee; of buhrstone, plaster of Paris and salt waters; of lead ore being worked in Jefferson County; of iron being worked at Bell's and Napier's furnaces in West Tennessee; and of finding a huge claw in the White County cave and huge tusks and teeth in various parts of the state.

We thus see that marble and lead were then known and the latter mined in East Tennessee, and that two furnaces were in operation in our western iron belt.

In 1828, Porter gives some brief notes on the geology seen in a journey from Natchez through Nashville to Louisville. He mentions mountains of flat lying limestone covered with cedars south of Nashville, and says some of them were capped with clay slate. In these we recognize the Lebanon or Glade limestone of Safford, and the overlying Chattanooga and Tullahoma shales.

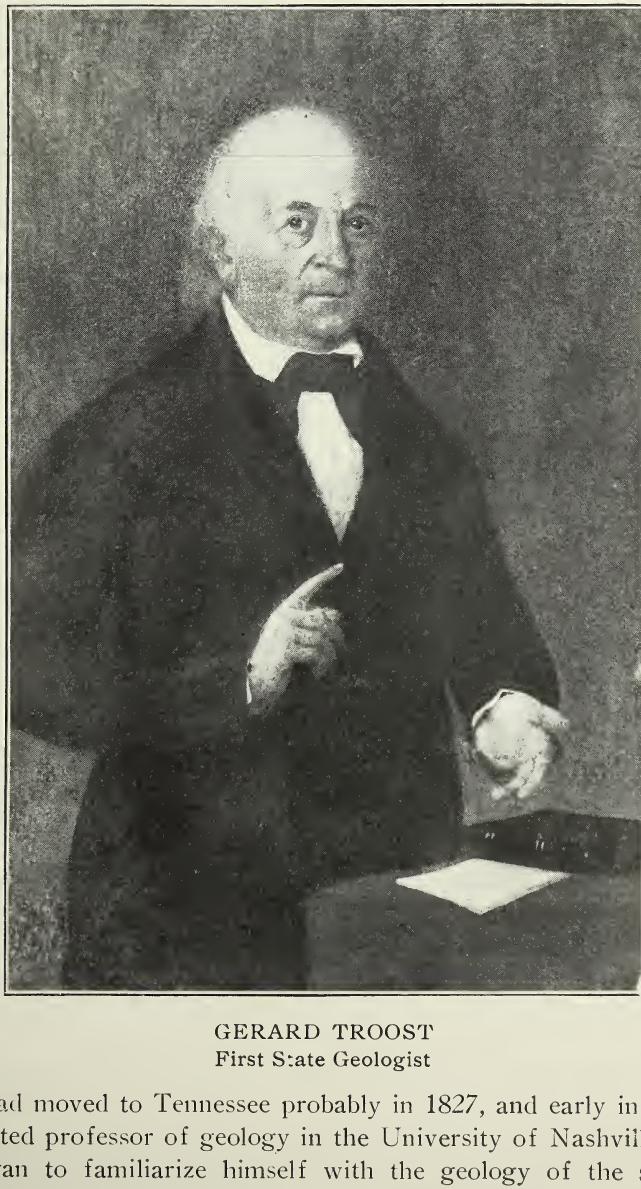
The next year in a brief article in Vol. 16 of the *American Journal of Science,* Vanuxem identified the lower rocks of Ohio, Kentucky and Tennessee, with the Trenton of New York, thus making perhaps the first definite correlation of Tennessee rocks with those of New York. He called attention to Maclure's errors, especially to the one of assuming all horizontal rocks to be Secondary, and declared that inclination is fallacious for discriminating age, that fossils are the first criterion, and the position and mineral character are subordinate.

In 1831, Doctor Ramsy read before the Medical Society of Tennessee at its first annual meeting a paper with the suggestive title, "The Medical Topography of East Tennessee." His opening sentence is: "The influence of climate and of physical causes in general on the human system suggests the propriety of introducing the following notice of the medical topography of East Tennessee, with a brief reference to the face of the country, its geology and atmospheric vicissitudes." He then describes the climate, geology and medicinal springs of that section of the state, and remarks that although the rocks of East Tennessee are generally regarded as of Secondary age—as Maclure and others following him believed—yet they are really older and should be grouped with the younger part of the Transition age, as it was then known. It will thus be seen that this noted physician and Tennessee historian not only had advanced ideas as to the relation between topography, geology, climate and disease, but knew enough of geology itself to correct erroneous views then held as to the geology of the region in which he lived.

This may be said to end the preliminary periods in the history of Tennessee geology. They were characterized by occasional, unorganized individual effort, most of which was incidental and cursory, and the net results were not of great importance.

### Period of First State Geological Survey.

The next period was one of organized effort, and may be said to date from the delivery, to the State Legislature on October 19, 1831, of an address on the geology of the state by Dr. Gerard Troost. Doctor



GERARD TROOST
First State Geologist

Troost had moved to Tennessee probably in 1827, and early in 1828 had been elected professor of geology in the University of Nashville. He at once began to familiarize himself with the geology of the state, and from the above mentioned lecture, which was a plea for the establish-

ment of a state geological survey, we find that he had soon become well informed as to the state's natural resources, so far as they were then known.

It is of interest to see from this address what he had already learned in his geological excursions over the State. He knew of the chief occurrences of zinc, lead, manganese, gold, marble and slate, but regarded these as subordinate in value to the iron and coal. "I look forward with full confidence," he said, "to the time when our Cumberland Mountains, rich in excellent iron ore and coal, will become the Birmingham of the West." The marble he regarded as "equal, if not superior, to the finest Italian." He was evidently of far vision—probably the original conservationist—for he urges that the owners of coal property should not be allowed to take out the part most easily removed and abandon and lose the rest, but says that it is "of the highest importance that this kind of property be placed under proper regulations, which would put it out of the power of the present owner to deprive his successors of the benefits, which, under proper management, would accrue to them,"—all of which is good doctrine today—and probably is as little practiced as in his day.

He urged that it was of the greatest importance that the inhabitants of new states should become acquainted with the natural capacities of their country. The address seems to have speedily produced results for the Legislature established a geological survey, and on December 21, 1831, Doctor Troost was appointed State Geologist and continued as such until February 4, 1850. This was the first persistent attempt on the part of any state or country to maintain for any considerable time an official geological survey. The first state geological survey ever established was by North Carolina in 1824, but it was short lived, ending in 1827. The attempt in South Carolina in 1825 was even shorter as it lasted but the one year. The third attempt was by Massachusetts, which planned a geographic survey of the state in 1830, but added, as an afterthought, first a geological, and still later a biological examination. The geological survey of Massachusetts lasted for three years.

The appropriations for the Troost survey, renewed biennially for nearly twenty years, first gained recognition for the idea that the continued maintenance of a bureau for the investigation and development of its natural resources is as proper and beneficial a function of state government as the maintenance of bureaus of health, education, or agriculture, and this idea has come to prevail in practically all of the progressive states of the Union.

The official results of Doctor Troost's work as State Geologist were embodied in ten biennial reports, of which the first, second and tenth were never published. Of those that were published very few copies are in

existence today. The unoffcial results include a number of articles published chiefly in the *Transactions of the Geological Society of Pennsylvania,* and in the *American Journal of Science,* a full list of which is given in the bibliography appended to the writer's article on Doctor Troost in the *American Geologist* for February, 1905, where additional details concerning his life and work may be found. This unofficial list also includes a monograph on crinoids that was submitted to the Smithsonian Institution and after a long and unfortunate delay has recently been revised by Miss Wood and published as *Bulletin* 64 *of the U. S. National Museum,* as is more fully related on page 214.

The address delivered to the Legislature in 1831 is generally regarded as the first report, and is even sometimes catalogued as such, whereas in reality it was merely a plea for the establishment of a survey. The first report was presented at the called session of the Legislature in 1832, but was not published. It contained a general account of the more prominent geological features of the State, so far as they were then known to Doctor Troost, a detailed description of Davidson County, and an outline of the extent of the coal-bearing area of the state. It may also have included a description of parts of some of the counties adjacent to Davidson that were included in the second report. An extract from the first report is given in the *Transactions of the Geological Society of Pennsylvania,* Vol. 1, pp. 240-243.

The second report was presented at the regular session of the Legislature in 1833, and the succeeding reports at the biennial sessions that followed. The second report was referred to a committee who recommended that instead of publishing it a brief summary prepared by themselves be published instead. From this summary* we learn that it contained a general outline of the geology of the State. The eastern part of the State belonged to the Transition, the Cumberland Plateau to the coal formation, which rested on an oolitic limestone that overlies the limestones of Middle Tennessee, and is overlaid by argillaceous and siliceous rocks that contain rich iron ores, and these in turn are overlaid in Western Tennessee by Tertiary formations. He then describes the geology of Davidson, Williamson and Maury counties, and states that he had begun the analysis and study of the various soils of the state as an aid to agriculture. He was convinced that the eastern part of the State was especially rich in mineral resources, the finest marbles abounded, and rich iron deposits already supported a number of iron works then in operation.

In the third report the coal area of the state is delineated on a map and briefly described. Attention is called to the possibility of mistaking

*House Jour. for 1833, pp. 303-305.

the black shale for coal or roofing slate. The marl or rotten limestone of the Cretaceous is described and the fertilizing properties and methods of using it are set forth. The iron ores of the western iron belt are referred to briefly and twenty-seven furnaces or more are mentioned as in operation in that belt, while in the eastern part of the State there were a number of others. There is added from the unpublished second report the result of the investigations of the soils of Davidson, Williamson and Maury counties.

Gold was discovered in the Ocoee district on Coker or Coqua Creek, and in the Tellico River in 1830, and for some years created so much interest and excitement that the Legislature, in 1836, requested Doctor Troost to make a special examination of that district. The results of this examination are given in the fourth report after an introductory discussion of the principles of geology and a description of the divisions of the rocks from the oldest to the youngest. In this discussion he alludes, with evident disapproval, to the new terms Silurian and Cambrian, "by which the geological nomenclature, adready redundant in the extreme with insignificant, barbarous, or silly words, has again been enriched." He believed like the Rogers brothers that local names should not be used in scientific nomenclature, because both of their meaningless character and of national or local prejudices and jealousies. The report proper describes the rocks of the Ocoee district with its gold, marble, slate, and iron. He seems impressed with the relation of the Sequatchie Valley to the Tennessee River, and suggests that this river may have once cut across Walden's Ridge and gone down that valley. In a note he adds a list of the fossils of the mountain limestone and of Pleistocene mammals found by him.

In the fifth report Doctor Troost gave a general description of the geology of the whole State, accompanied by a colored geological map and an east-west vertical section across the state. From these it is evident that he believed the rocks of the Nashville basin and the surrounding Highland Rim to belong to the same division, and to be younger than the tilted rocks of East Tennessee. The soil and mineral resources of Cocke County were described, especial attention being given to the iron ores. The iron furnaces and ores of other parts of the State were noticed briefly, and silver ore and mineral waters were mentioned. In an appendix was given a considerable list of fossils with descriptions of a number of new species.

The first part of the sixth report is devoted to the geology of Middle and East Tennessee, which is redescribed and assigned to the Cambrian and Silurian. The rocks of all Middle Tennessee are referred to the Silurian as the term was then used by Murchison, and the fossils found

in them are listed, and some of them described. There is a description of Sevier County, accompanied by a map, and notes are given of the occurrence of alum, saltpetre and iron ore and of the composition of a number of mineral waters.

In the first part of the seventh report the geology of Davidson County is described with detailed references to the minerals found, and a brief notice of the fossils of the county, of the iron ore of the Harpeth River region, and of the meteorites of the state. The green sand of McNairy and adjoining counties is described at some length, and its probable future importance stressed. There is a list of the reptiles and fresh water shells of the State, and in a supplement there is a brief account of the lead and zinc ores of East Tennessee. A colored geological map of Davidson, Williamson and Maury counties accompanies this report. This map was originally intended to accompany the second report which, as has been seen, was never published.

The eighth report describes some four routes by which a railroad might be constructed from Nashville to Chattanooga, and directs attention to the coal, iron, limestone and other minerals of economic importance in the region that would be traversed by the road. In obedience to a resolution of the Legislature, a report on the limestone, or so-called marble, of Caney Fork was added.

In the first part of the ninth report there is a description of Jefferson County, while in the second part the various zinc ores of the state are described, some analyses of them are given, and a number of types of furnaces for zinc smelting are described and illustrated by a sheet of mechanical drawings showing the plan of construction of each. The processes of extracting zinc from its ore and of making brass are given. From the attention given to zinc deposits, Doctor Troost must have regarded them as promising.

The tenth report was presented to the House of Representatives on January 12, 1850, and seventy-five copies were ordered to be printed for the use of the House. No edition was ever published, and neither the manuscript nor any of the copies ordered printed for the House can now be found. It would seem from an editorial note in the *American Journal of Science,* based on a letter from Troost himself, that the report was very brief, and was accompanied by his monograph on the Crinoidea. The Legislature declined to publish this monograph, but it was later accepted by the Smithsonian Institution, and has finally been published, as may be seen by reference to page 214.

In addition to his reports as State Geologist, Doctor Troost published in 1834 and 1835 in the *Transactions of the Geological Society of Pennsylvania,* a number of papers describing various Tennessee fossils and

rocks, and sent one paper to the *Geological Society of France,* in which a number of new forms were illustrated and described. A decade later, from 1845 to 1848, he became interested in meteorites, a good number of which had been found in the State, and published several articles descriptive of them.

It is difficult to summarize correctly and briefly the work of our first State Geologist. Much of his work was a labor of love for the meager appropriation scarcely more than paid his field expenses and hence limited his work to the study, either of merely the broader geological and economic problems of the state, or of the more detailed problems of only very restricted areas. As a result, while the general geological features of the state were soon determined, yet the details of very little of it were worked out, even in the general way in which details were then understood.

Troost determined the general distribution within the state of the various rock formations then discriminated and located and described the mineral deposits of chief value or greatest promise. He delineated the coal area of the state, called attention to the importance of both the eastern and the western belts of iron ores, regarded the marble as very excellent in quality, and the roofing slate, lead, zinc and various other materials of East Tennessee and the green sand of West Tennessee as probably of much value. He did not regard the gold of the eastern nor the lead of the middle part of the state as of great promise. He recognized how valuable the study of soils might be made to the farmer, and made numerous analyses of soils, minerals and mineral waters. The main purpose of his work was economic, and it undoubtedly gave important guidance to the efforts then being made to develop the coal, iron, marble and other resources of the state.

The two decades from 1830 to 1850, almost coextensive with the Troost survey, were a period of rapid development in the infant science of geology, and of rapid increase in our knowledge of the geology of the country at large. Although in Tennessee geology, most of our increased knowledge during this period was due to the labors of Doctor Troost, yet certain others made contributions that are deserving of notice.

In a work entitled a *"View of the Valley of the Mississippi,"* published in 1832, the author, Robert Baird, gave a description of Tennessee, that contains frequent references to her mineral resources. His information was compiled from various well known sources and adds comparatively little to our knowledge, and practically the same may be said of *Flint's History and Geography of the Mississippi Valley,* published the same year. He gives the same lists and localities of minerals and the same supposed petrifactions of turkey eggs, horse hoofs and other freaks that were given by Haywood in 1823.

From an article by Jacob Peck in the *American Journal of Science* in 1833, it is evident that mining was then receiving its first serious attention in East Tennessee, due doubtless in large measure to the interest aroused by the discovery of gold in 1830, as related by Troost in his report on the Ocoee district. His map gives coal and iron along the east face of the Cumberland, and marble, lead, zinc and gold in the valley region to the east.

In 1834, Morris gives in his *Tennessee Gazetteer,* a good topographic description of the state, with brief notes on the more important minerals.

In 1834, Featherstonhaugh crossed East Tennessee and the Cumberland Mountains and spent some time in Nashville, where he at once sought Doctor Troost, of whom he gives in his *Excursions Through the Slave States,* published in 1844, an intimate and interesting account as he found him with his students, his minerals and fossils—and his pet snakes. The two examined together the geology about Nashville and made excursions into the Harpeth hills. Featherstonhaugh recognized Silurian strata in the rocks of East Tennessee, and saw that the rocks of the Cumberland Plateau were of younger age. He gave a section down the Cumberland from the Carboniferous to the rocks about Nashville, and referred incidentally to the minerals about Nashville and elsewhere.

The decade from 1830 to 1840 was one of marked activity in many states in promoting schemes for internal improvements, such as canals, highways and railroads. In 1836, Tennessee entered upon such work by appointing A. M. Lee, State Engineer and directing him to make surveys for certain proposed railroads and turnpikes. In the report rendered by him in 1837, he describes in a clear manner the topographic features of the counties examined and gives the elevation of numerous points. This is probably the first determination of the actual elevation of points over the general surface of the state, unless Col. S. H. Long had done some such work in examining a route across the Cumberland Plateau in 1834. Colonel Long, in 1830, had examined the Tennessee River from Knoxville to Chattanooga, and determined some relative elevations, but these were probably not connected and were not tied to sea level for many years afterward.

Hall, in a book of travels, published in 1840, describes the minerals and geology of the region about Nashville, evidently getting his information from Doctor Troost.

In 1842, F. G. Smith, published in London, a pamphlet setting forth the resources and conditions in East Tennessee for the purpose of attracting immigration. From it one learns that there were then in upper East Tennessee "extensive" iron furnaces, nail mills and foundries, and that there had recently been started near Rogersville, an establishment

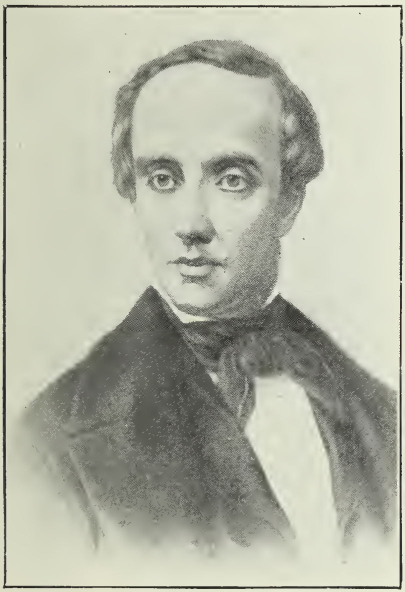
for quarrying and working the marble of that locality. This was the earliest marble works of the State, and it is said to have been organized through the personal efforts of Doctor Troost, so great was his faith in the value of the marble there.

At a meeting of the Association of American Geologists and Naturalists, held in Boston in 1842, W. B. and H. D. Rogers presented a paper on the physical structure of the Appalachian chain. They had studied the folded mountain belt of East Tennessee and recognized the prevailing steep southwestward dips and the fracturing and frequent faulting on the northwest limb of the anticlinal ridges. Troost and others had observed these dips, but no one else had made a special study of that particular type of structure since made classic by this work of the Rogers brothers and now known as Appalachian structure. This paper was followed at the 1843 meeting by a discussion by H. D. Rogers of the Marcellus or Black Shale in which it appears that he and his brother had traced it south to its disappearance at the end of Clinch Mountain in a great fault, and that they had again found it on Caney Fork and in the Harpeth ridge and elsewhere in Middle Tennessee. This was in turn followed by the presidential address of H. D. Rogers in 1844 in which he shows an intimate personal knowledge of the stratigraphy and paleontology of the East Tennessee rocks. He and his brother had doubtless given more time to the study of that section, and had a better knowledge of its complex structure than any one else at that time. He refers to the great value of the pioneer work that had been done in Tennessee by both Troost, whose work we have already discussed, and by Owen, whom we will next consider.

D. D. Owen joined Doctor Troost as a volunteer assistant in 1833, and made a reconnoissance of a considerable part of Middle and West Tennessee. Later, while engaged in survey work in neighboring states, he probably made special trips to certain other parts of Tennessee for study and comparison, and may have maintained a correspondence with Doctor Troost and thus kept in touch with developments in Tennessee geology. Certain it is that he shows considerable knowledge of the sequence of the formations in the Cumberland Plateau and Middle Tennessee and delineates some of them with a fair approach to accuracy on the map accompanying his article on the geology of the western states of North America, read in 1842 before the Geological Society of London, and published in 1846. He also presented the subject in 1843 before the Association of American Geologists and an abstract was published in the *American Journal of Science* of that year.

The Tennessee data in both the article and the map were given partly

on his own and partly on Doctor Troost's authority. The Tennessee part of his map is an improvement on Troost's map of 1838, in that the rocks of Middle Tennessee that had been grouped together by Troost, are separated in downward sequence into the pentremital limestone, lower siliceous (Safford's Tullahoma), argillaceous (Chattanooga shale) and calcareous (Silurian and Ordovician). He did not, however, recognize the lowest or calcareous rocks about Nashville as occupying an elliptical area entirely surrounded by a rim of the higher rocks. The realization of this fact was reserved for Safford some ten years later.



D. D. OWEN

It was doubtless to the section and information furnished by Owen, that James Hall owed his recognition of the southward extension of the Cincinnati axis to the Nashville region,* since he had not visited the region in person.

In 1846, Loomis, who was familiar with much of the New York section, identified the Ordovician, Silurian and Devonian in the Harpeth hills with the corresponding formations in New York on the basis of both lithological and paleontological similarity.

In the same year Carpenter exploded the myth or hoax that the gigantic fossil man 18 feet high, then on exhibition in New Orleans, had recently been found in Tennessee by showing that it was merely a portion of the remain of a mastodon skilfully arranged and appropriately restored.

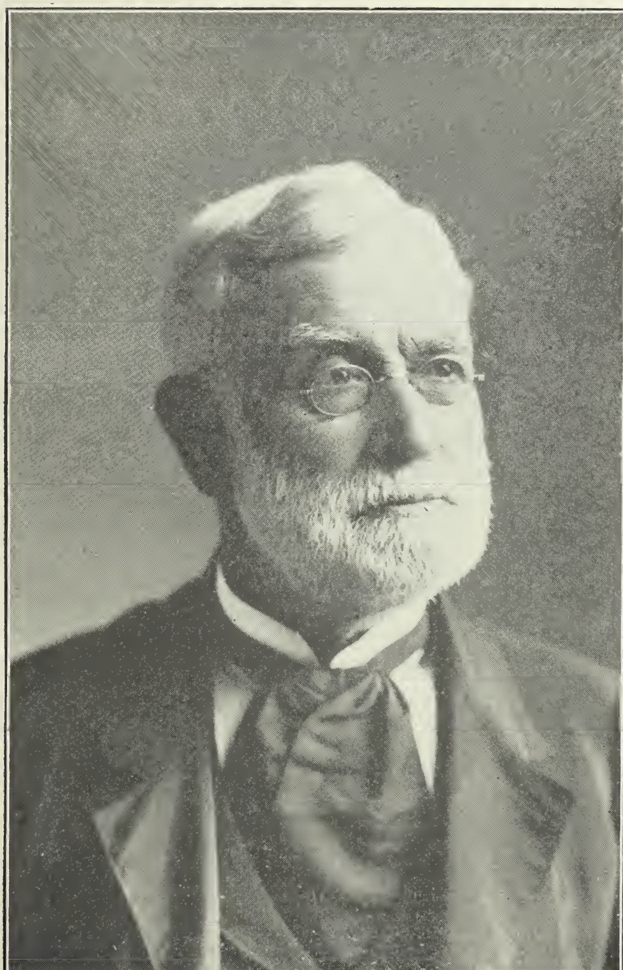
Lyell, also in 1846, when on his second visit to the United States, passed up the Mississippi River studying the alluvial deposits and the effects of the New Madrid earthquakes of 1811-12. He landed at New Madrid and examined the adjacent region in Missouri, but did not cross into Tennessee. His observations on the bluffs and alluvial plain of the Mississippi, while void of many specific references to this State, contain much that is applicable to it.

*Hall, James, *Assoc. Amer. Geol. and Nat., Trans.*, p. 288, 1843, and *Geol. N. Y.*, Vol. 4, p. 513, 1843.

THE DECADE FROM 1850 TO 1860.

We have seen that in matters of classification Doctor Troost adhered strongly to the old terms, Primary, Transition and Secondary, and only toward the last came to use the barbarous new terms Carbrian and Silurian. He deprecated so strongly the use of local geographic terms to designate geological formations, that he would neither adopt local ones nor use the New York ones then coming into vogue, but preferred descriptive terms, such for example, as the blue or the cliff limestone, the aluminous slate or the siliceous stratum. The time was ripe, however, for the adoption of a more detailed classification, and, whether to be deprecated or not, the trend of the times had determined that this classification should have a geographic terminology. The use of the old terms ended with Troost's death in 1850, and a new terminology was introduced the succeeding year by the publication of an article in the *American Journal of Science* on the Silurian basin of Middle Tennessee by James M. Safford, a young, able and enthusiastic geologist, who had taken the chair of natural science at Cumberland University in 1848, and at his own expense had explored the Nashville region so energetically that he was able in the above article to classify, describe and map the rocks of the Nashville basin in essentially the manner they are classified today. He recognized the Nashville region as a basin eroded from a low, broad dome, and recognized a marked unconformity between the black shale and the Nashville rocks. The oldest of these rocks he called the Stone's River group; next came the Nashville, and each of these had three subdivisions; then the Harpeth limestone—our Silurian; then the Black shale; and finally the Siliceous group with two subdivisions. These divisions were all based on both lithological and paleontological characters and lists of the fossils characteristic of each were included. This paper and the accompanying map evinced an unusual amount of energy as well as great rapidity and clearness of grasp of stratigraphy and structure, and really marked the beginning of the modern era in Tennessee geology.

This was followed by Safford's reading a paper at the Cleveland meeting of the American Association for the Advancement of Science in 1853, showing by paleontological data that the Stone's River group was equivalent to the Black River group of New York, and the Nashville group to the Hudson group; that the intervening Trenton group of New York was not represented about Nashville by a distinct series of rocks, but that the fossils of the lower Trenton were mingled with the Stone's



JAMES M. SAFFORD,
Second State Geologist

River group and those of the middle and upper Trenton with the Nashville group. This same year Safford's Silurian basin map was republished with a brief description of the topography, in the *Southern Journal of Medical and Physical Science.*

Meantime James Hall at the Albany meeting of the American Association in 1851 called attention to the excellent work of Safford in Tennessee, and to the Silurian basin article and map, and correlated Safford's divisions with the New York ones by means of the collections of fossils that he had aided Safford in determining. The cordial relationship thus early established between Hall and Safford continued unbroken as long as they lived.

Safford published no further articles until his first report as State Geologist was rendered to the Legislature in December, 1855. Before sketching the work of the Safford Survey, which extended nearly to the close of the 1860-1870 decade, brief notice will be taken of the contributions of others during the decade from 1850 to 1860.

Geological maps first demand a word. Marcou published a geological map of North America in 1853, which the writer has not seen. The Tennessee portion of this map could not have been based on personal observations, since Marcou did no work in this state, but must have had the maps of Troost and Owen as its sources. Although Safford's map of the Silurian basin of Middle Tennessee had been published in 1851, and was far in advance of any other mapping that has previously been done in the State, yet it seems not to have been used by Marcou, judging by Hitchcock's geological map of the United States, published in 1854, which Marcou claimed had been taken from his and Maclure's map. If the Tennessee portion of Hitchcock's map is taken from Marcou, then Marcou must in turn have himself derived his Tennessee data from Owen for the mapping of Tennessee by Hitchcock — especially in the peculiar curved or hooked outline given the formations in the Harpeth River region of Middle Tennessee is essentially alike that of Owen's map of 1842.

This may all be said and yet cast no reflection on either Hitchcock or Marcou since all compilers of general maps must necessarily depend upon the mapping of others for very large portions at least of the area covered. They may both be criticised, however, for not delineating Middle Tennessee as Safford had mapped it in 1851 instead of as Owen had mapped it in 1842.

During several decades the development of both the limonitic iron ores of the western iron belt and the hematite ores of the eastern part of the state had been in progress, and we have already noticed the state-

ment made by Troost that in 1835 there were twenty-seven or more furnaces and forges in the western belt. The census of 1840 gave Tennessee third rank in the United States in iron production. In 1849 there were reported forty-seven furnaces and ninety-two bloomaries and rolling mills in the State. With an annual output of 30,200 tons of pig iron, according to the census of 1850, the State then held fifth rank in iron production. This production increased steadily until the Civil War. In 1854 it was some 40,300 tons, worth $2,000,000, and in 1856 was estimated at about 50,000 tons. These furnaces were all small, as they were everywhere at that time. Practically all of this iron was made with charcoal, and had a wide reputation for exceptional strength and toughness.

The first important development of the Ducktown copper deposits began in 1850, although the first discovery had been made about 1843, when searching for placer gold, and a trial shipment of 90 casks of black copper ore had been made to Boston in 1847. An unsuccessful attempt had also been made in 1847-8 to use the gossan of the copper vein for iron production, but it was found to be red short and worthless. By 1853 the production of copper had attracted general attention, and geologists were attracted to the region to study and report on the ore deposits. Among these, J. D. Whitney and W. P. Blake visited the region in 1853, and Whitney describes the rocks as highly metamorphosed schists and the copper-bearing veins as weathered above ground water level, the copper leached out of the gossan by surface waters and carried down and deposited in concentrated form as the rich black ore found at water level, while below this the vein consisted of unchanged sulphides. This Ducktown copper deposit thus early described by Whitney has become a classic example of surficial weathering and enrichment at ground water level. This description was also embodied in 1854 in his *Metallic Wealth of the United States.*

In 1855, Tuomey, after visiting the Ducktown region, concluded that the rich black copper ores were derived not from lean sulphides, such as those found below ground water level, but from a rich copper sulphide that he thought had existed in the upper weathered part of the vein, and thought that similar pockets of rich sulphides might be found at greater depths. He failed entirely to recognize concentration as having played any part in the changes that had occurred. Whitney took exception to one of Tuomey's statements, and in an article a few months later in the *American Journal of Science,* repeats very fully and clearly his belief in weathering and concentration as responsible for the enrichment at ground

water level. These Ducktown deposits of rich black copper oxide were probably the first ores in this country to be recognized as due to secondary enrichment and the clear recognition of this process as an important factor in the formation of ore deposits it would seem should be credited to Whitney.

A history of the copper discovery and development at Ducktown, with a description of the geology and ore deposits, was given in the *Southern Journal of Medical and Physical Science* in 1855, by Currey and Proctor.*

In the winter of 1854-5 Ansted made an examination of the copper region, and in 1857 described the veins and the enclosing country rock in the *Quarterly Journal of the Geological Society of London.* He thought that, independently of direct aqueous action, the veins were filled by chemical force by segregation from the country rock or below and concluded that the black copper came in by a different and subsequent action from that which formed the lower sulphides, and hence is not the decomposed derivative of the present sulphides.

In 1859 Shepard made a report on the Ducktown region. From it we learn that they were then roasting and smelting the sulphide ores and producing a 40 to 50 per cent matte for shipment. The fumes from the roasting pens were killing the vegetation. The mine waters were being run over scrap iron for the recovery of their copper content. The report contains nothing new concerning the geology or ore deposit.

Just as there was much activity in iron and copper production from 1850 to 1860, so there was a marked increase in coal production during this decade. Kain, it will be remembered, said in 1819, that coal was then mined near Knoxville, but was used only in forges, so great was the abundance of wood. The next specific reference is in 1835, in Troost's third report, pages 4 and 5, where he says: "A few miles east from Pikeville, in Bledsoe and Rhea counties, are several outcrops of coal, some of which are opened and furnish the coal for several of the black-

*Currey had been a pupil and was later a voluntary field assistant of Troost, and although a physician, had retained an interest in geology. He was then editor of the above mentioned journal, and was writing for it a series of articles on the geology of the state that were later to appear in book form, as we shall see presently. Proctor was state assayer, and in this capacity had become familiar with the deposits and developments at Ducktown, and both Currey and Safford acknowledged their indebtedness to him for information on the copper region. Safford credits him with the data on which he based the map of the region published as an inset on Safford's first geological map of the State. Aside from this we know nothing else of Proctor nor of how long the office of state assayer was maintained.

smiths' shops of Washington, Pikeville and surrounding country. Continuing on Walden's ridge from these coal banks in a direction from southwest to northeast, we find several beds, one lately opened by Mr. Gillenwaters, and another near the turnpike road from Kingston to the Crab-orchard belonging to Mr. J. Kimbrow. They are worked at present, and the coal transferred to New Orleans by boats, which are loaded in the Tennessee River, which is only three miles from the coal bank." Again he says: "In Fentress County several pits have been opened by General Rodgers, who sent the coal down the Obey and Cumberland rivers."

Mining must have continued regularly at Gillenwaters' and at Kimbrow's, for in his ninth report, published in 1848, Troost says the coal from these places was highly esteemed on the Mississippi steamboats as a steam coal, and in New Orleans as a gas coal. It is probable that the shipment of coal down the Cumberland from Fentress County was not found profitable and was soon abandoned, as Safford says in his first report, presently to be described, that 21,428 tons were brought down the Cumberland from Kentucky in 1854, but makes no mention of Tennessee production being shipped down the river.

Although coal mining, as we thus see, had become established before 1850, yet it was confined to a very few places, and the production was small and subject to much variation. The general outlines of the coal-bearing area of the state had been made known by Troost, but no work had been done either to determine the number of coal seams at any given place or to trace the areal extent of any given bed, so that Whitney says in 1854 in his *Metallic Wealth of the United States* that scarcely anything practical is known of the coal fields of Tennessee. In 1854 the production of coal in Tennessee was only 8,300 tons.

J. P. LESLEY

Lesley in an article on the Cumberland coal fields in Tennessee in 1855, called attention to the coal in the Sewanee-Tracy City region, and gave details of sections at several places where coal was mined for local use. He had probably investigated that region for the Sewanee Mining Company, which had been organized in 1854, and soon began the construction of a branch railroad from Cowan up the mountain to Sewanee, over which they began shipping coal in June, 1855. The completion of the Nashville and Chattanooga railroad in 1854 led to the opening about this same time of coal mines in the Raccoon Mountains near Chattanooga,

and the increase in coal mining was so great that Safford estimated the production in 1855 at 20,784 tons.

In 1859 Buckley published the results of his barometric measurements of the elevations of a number of high peaks on the North Carolina-Tennessee line, made in 1858, and added the elevations of a number of other points determined by Guyot in 1856. This was probably the earliest barometric work of any consequence within the state.

Shortly after Doctor Troost's death efforts were made to reëstablish the geological survey as an aid in developing the mineral resources of the state to which much attention was then being directed, as has been seen from the sketches given of the iron, copper, and coal development.

Doctor Richard O. Currey wrote with this purpose in view a series of articles that were published in the *Nashville Banner* in 1853, and later formed the basis of a more extensive series of articles published in his *Southern Journal of the Medical and Physical Sciences* at intervals from 1854 to 1857 and then republished in book form.

When the Legislature reëstablished the geological survey in 1854, Doctor Currey was a candidate for the position of state geologist, and in furthering his candidacy had prepared and published a geological map of the state. This map is probably exceedingly rare, as it was issued with Currey's Journal, which had but a limited circulation. It is not generally known, as Marcou does not list it in his *Mapoteca Geologica Americana,* and the only two copies the writer has ever seen are in the geological library at Vanderbilt University. In it all of West Tennessee, except the Mississippi River alluvium, is regarded as Cretaceous. In Middle Tennessee the outlines of the pre- and post-Devonian formations are traced with considerable accuracy, and the coal area is given. In East Tennessee, the formations recognized are the Devonian, Upper and Lower Silurian, Metamorphic and Primary, all of which are represented in the accompanying section, as dipping uniformly to the southeast and repeated by faulting. The chief advance when compared to Troost's map was in the better representation of Middle Tennessee, where in 1851, Safford had outlined the geology of his Silurian basin. When Currey republished his geology in book form in 1857, it is of interest to note his frank endorsement of the geological map of the state that had meanwhile been published by his successful rival for the position of state geologist by saying in his preface, "Professor Safford has published an excellent map to accompany his First Report, which, by his kindness, I am permitted to obtain for insertion in the present volume."

Currey described the general geology and structure of the State very

much from the standpoint Doctor Troost had done. The main portion of the work, however, was devoted to the economic mineral resources of the state.

In February, 1854, the General Assembly reëstablished the state geological survey, and in March, Prof. James M. Safford, of Cumberland University, was elected State Geologist. He at once obtained leave of absence from the university and entered upon the active discharge of his duties. He had for four years or more, at his own expense, spent his vacations traveling over the state studying its geology, and had published his first article as has been seen in 1851. In December, 1855, he submitted his first biennial report. It was a geological reconnoissance of the entire state, and showed that its author had already gained a remarkably clear insight into the intricacies of the structure and formations of the state. It also exhibited the well balanced proportion and slear insight that was characteristic of his later and larger work.

The first chapter set forth the objects and utility of the survey, and the second gave a concise topographic description of the state. Then followed the main portion of the report devoted to the economic geology of the state in which were discussed the occurrence of iron, copper, lead, zinc, gold, silver and aluminum—the "new metal"—, coal, lignite, marble, marl, salt, cement rock, roofing slate and other materials too numerous to mention. Then followed a chapter on the geological structure of the state in which the complex folding and faulting of East Tennessee, and the effects of erosion there and elsewhere in the State, were clearly described. A final chapter was devoted to the geological formations of the State, with their great range from ancient gneisses and schists to recent alluvium.

In its quick grasp, admirable balance and due proportion, this report of only 164 pages, covering the entire state, and rendered less than two years after the beginning of official work, has rarely been equalled. Merrill pays it high tribute by saying:* "This report shows on the part of Safford a thorough insight into the intricacies of the structure of the state and an ability to grasp the salient features and master the broader problems in a manner perhaps not realized by many of his contemporaries and successors." This report was accompanied by a geological map of the state printed in black and white, and showing by a system of numbers or names, the fourteen formations that he had discriminated. The scale was 12 miles to the inch, with an inset map of the copper region on a scale of ¾ mile to the inch. A section east and west across the state gave a clear idea of the structure, and the map as a whole gave a good idea of the surface geology, though the later edition of the map issued

*Merrill, G. P., *Rept. U. S. Nat. Mus.*, for 1904, p. 458.

with the 1869 report contained much additional information, especially as regards the smaller details of structure.

The second biennial report rendered in 1857 was merely a report of progress consisting of eleven pages. The two years since rendering the first report had been spent filling in details in the broad outline sketched in that first report. This detailed work was not yet finished, and until it had been, it was not advisable to attempt a final report. This brief report was the subject of caustic criticism by Doctor Currey in the November, 1857, number of his Journal. The criticism is explained by the first marginal annotation penciled by Safford in his copy of the Journal, which is as follows: "This ebullition of temper took place immediately after the editor's defeat in the Legislature by 'Safford'—hence his ire and misrepresentations." Other annotations show that Safford was amused rather than offended by the editorial. The ebullition, indeed, seems to have spent itself before the editorial was finished, for its concluding sentence is, "But the present State Geologist deserves credit for his systematic arrangement of this work, and for his accurate map of the geology of Tennessee, and trustingly we look forward two years to a report that will contribute to the wealth of the state." The incident passed without affecting the friendship of the two men.

The third biennial report was rendered in 1859 and like its predecessor, was a brief statement of progress only. He estimated that a final report, the first hundred pages of which had already been prepared, would require about a year's additional time for completion. This work was prosecuted vigorously, and part one, discussing the physical geography of the state, and embracing the first 125 pages of the final report, had been printed in 1861, when the Civil War stopped the publication, and the completed report did not appear until 1869. Consideration of it will be postponed until other publications that preceded it have been noted.

Safford contributed a short note to the *American Journal of Science* in 1858, calling attention to an important unconformity in Middle Tennessee between the Ordovician and the Devonian, caused by the existence in that region during Upper Silurian and Lower Devonian time of an island of low-domed shape and structure, and the next year in another brief article in the same Journal, announced that the shape of the marble and some of the other formations of East Tennessee showed that they were deposited in long, narrow troughs, whose existence indicated that Appalachian folding had been initiated in the Silurian. This idea has received strong confirmation in recent years from studies made in the region by various paleontologists, some of whom were evidently ignorant of this early work of Safford, as may be seen by reference to page 216.

The several railway surveys made between 1850 and 1860 furnished the elevation of many points, and furnished bases from which other points might readily be determined. Professor Guyot, who had been interested for some years in determining elevations in the northern Appalachians, began similar work in 1856 in the Southern Appalachians, and determined the elevation of a number of gaps and peaks along the Tennessee line. Some of these were published in the Asheville and other local newspapers, and are given by Buckley in 1859 along with determinations made by himself in 1858. Guyot published his elevations in the *American Journal of Science* in 1861 with a map of the region that unfortunately was on a scale too small to be of more than general value.

LEO LESQUEREUX

Lesquereux published in 1859 descriptions of some fossil plants collected by Safford near Summerville and thought to be of Pliocene age, and ten years later published descriptions of other plants from the Tertiary of West Tennessee.

## Decade From 1860 To 1870.

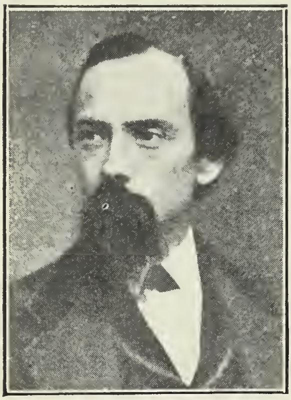
In the few years immediately preceding and following the Civil War numerous mining schemes were launched, and the prospectus for each usually contained a geological report on the property. In Tennessee these were usually zinc, copper, coal or iron projects before the war, but just after it most of the reports were on oil and gas lands. These numerous reports rarely contained anything of general geological value, and most of the projects were ill advised and amounted to nothing.

From 1860 to 1865, and later, a number of articles appeared on the Taconic controversy, and usually reference was made to Tennessee, especially to the Ocoee series of Safford's first report, but as they contributed no new facts and settled no controverted points, further reference to them here is unnecessary.

Humphreys and Abbott's *Physics and Hydraulics of the Mississippi River*, and Foster's *Mississippi Valley*, deserve mention as discussing matters pertaining to Tennessee in common with other states in the Missisippi Valley, but since they in no way pertain solely to Tennessee they need no detailed discussion.

In 1860 Hilgard published a report on the geology of Mississippi that contained much of importance to the student of West Tennessee geology. In Mississippi the Cretaceous and Tertiary formation are more clearly

differentiated, both in their fossil contents and in their lithological character than they are in West Tennessee, so that Mississippi becomes a vantage ground from which to attack the problems presented by these formation in Tennessee. Hilgard adopted Safford's term, *Orange sand,* but used it in a much narrower sense than Safford had in his first biennial report. As used by Hilgard it was synonymous with what is now known as the Lafayette, a formation that is widespread in its occurrence in northern Mississippi and West Tennessee, but is of so puzzling a character that it has not only caused much difference of opinion, but has even led a recent writer * to deny its existence at certain places, such as LaGrange, Tenn., where in reality it is well developed and should be readily discriminated.



E. W. HILGARD

Hilgard regarded it as of Quaternary age, and in 1866 returned to the problem of the origin of the Orange sand and other later bluff and terrace formations in an article in the *American Journal of Science,* in which he adopted Tuomey's idea that they were the result of the erosion, transportation and deposition caused by the sudden melting of the northern ice. Since then Hilgard and others have turned repeatedly to the problem, and yet the origin of the Lafayette is still a puzzle.

Safford published in the *American Journal of Science* in 1860 a note calling attention to the fact that the Calceola found in West Tennessee is in the Silurian, while the European species, with which it is usually considered identical, is in the Devonian. He named the Tennessee species *Calceola Americana.*

In 1862, Lesley presented before the American Philosophical Society a paper on the structure of the Appalachian Mountains † in which he conceived the Appalachian Mountains of the Great Valley region of southwest Virginia and East Tennessee to be grouped in pairs by great faults that extend for three or four hundred miles, and had fractured the rocks into parallel strips five to six miles wide. Each strip is tilted to the southeast so that the upper edge of one strip with Carboniferous rocks abuts against the under and Lower Silurian edge of the next strip, and as each strip has two hard sandstone horizons whose upturned edges resist erosion more than the intervening rocks, they stand out as a pair of mountain ridges, and the Great Valley will have as many pairs of

*Berry, E. W., *Jour. of Geol.,* Vol. 19, pp. 249-256, 1911.

*Lesley, J. P., *Amer. Philos. Soc. Proc.,* Vol. 9, pp. 30-38, 1865.

parallel mountains as there are parallel fault strips. This conception may be measurably correct for southwest Virginia, but must not be pushed too far for East Tennessee, where the tilted blocks include only exceptionally any Carboniferous rocks, and where the mountains are not always in pairs in each fault strip, nor are the fault strips so long or so regularly spaced as the article would lead one to believe.

In 1847 Ferdinand Roemer, a German, who had spent some two years studying the geology of Texas, stopped as he returned, in Nashville to see Doctor Troost, and was so strongly attracted by his collection of Upper Silurian fossils from the glades of Decatur and Perry counties that he spent some weeks in these counties collecting fossils. These were taken to Germany with him and were the subject of an illustrated monograph in 1860—*Die Silurische Fauna des Westichen Tennessee*—in which numerous species, especially of fossil sponges, were described and illustrated, and the correlation of the fauna with that of other regions in America and Europe discussed. Safford, in 1861, published a brief article in the *American Journal of Science*, calling attention to the fact that the fauna described by Roemer was not the only one occurring in the glade region, and giving a detailed section of the rocks of these counties. This work of Roemer has been largely instrumental in making the Silurian of Decatur and Perry counties classic ground for the fossil hunter, and its sponges are now known the world over.

Safford published, in 1864, in the *American Journal of Science*, an article on the Cretaceous and later formations of West Tennessee, in which he classifies and describes these formations as he does in his *Geology of Tennessee*, published in 1869.

In 1865 the U. S. Coast Survey published its first set of determinations of geographic positions in Tennessee.

In 1866, in an article on the geological position of petroleum reservoirs in Kentucky and Tennessee, Safford showed that oil had been obtained from Mississippian, Devonian, Silurian, and Ordovician rocks, the upper part of the Ordovician being the greatest producer.

In 1868, Bokum, as Commissioner of Immigration, published a small Tennessee handbook designed to attract immigrants and gave in it a brief, but good, resume of the minerals and soils of the state.

Safford's *Geology of Tennessee*, whose publication had been delayed first by the Civil War and later by the prostration that followed it, finally appeared in 1869. A statement from Safford to the Legislature in 1866 as to the status of the report shows that its preparation had been arrested at the beginning of the Civil War after the first 124 pages had been printed and several illustrations had been prepared. It was an octavo of 550 pages with eight plates of fossils and a colored geological

map of the State. Part I was devoted to the physical geography of the state, in which, after a brief description of the boundaries and climate, there was a detailed discussion of the features of each of the great natural divisions of the state. This part occupied the first 125 pages, and the next part occupied pages 127 to 446. This latter was the main part of the report and was devoted to a discussion of the geological structure and formations of the state. The next part, occupying pages 446 to 522, was devoted to minerals and rocks of special use, while the concluding part, pages 523 to 532, discussed the soils and agricultural features of the state. Appended to the section on the geological formations was a brief report by A. Winchell on some fossils found immediately above the Devonian black shale and considered by him to be of Kinderhook age. Safford appended at the end of the volume a brief note on certain fossils, especially tetradium, a description of some four species of which he had published in the *American Journal of Science* in 1856.

It is a well rounded, well balanced and eminently sane and clear cut presentation of the geology of the state and of its economic resources as they were known at the time of its preparation, now some sixty years ago. The writer knows no similar sized single volume on the geology of any state written either at that time or since that is the equal of Safford's work, and the general stratigraphic and structural features worked out by him without the aid of maps have stood remarkably well the test of modern detailed investigation and mapping. His work necessarily could not go into details and give the specific information that property owners and investors require today and obviously could not discuss such deposits as the blue, white, brown or nodular phosphates or the bauxites, the existence of which were not known at that time. It was unfortunate in appearing at a time when our people were still exhausted from the war and heavily burdened by debt, so that the development of our mineral resources, as of everything else, was then a slow and difficult process. This report has, nevertheless, exerted a very great influence in the industrial development of the state, especially directing pointed attention to our coal and iron resources. Many of the subsequent articles on Tennessee geology have been largely or wholly compiled from this work of Safford.

Although it is impossible to discuss here even briefly the detailed contents of this report, two topics, the Orange sand and the Ocoee, need mention. The term Orange sand was used by Safford in 1855 in his first report to include all of the Cretaceous, most of the Tertiary and the Lafayette of West Tennessee. We have already seen that Hilgard adopted the term Orange sand and used it for what we now know as Lafayette. Safford, in his 1869 volume, restricted the term Orange sand to the middle

or LaGrange member of the Tertiary. Other writers have also used the term in various senses, and so much confusion has thereby arisen that by common consent the term has been dropped. For a history of the varying uses see Hilgard and Safford's article in Volume VIII of the *American Geologist.*

The second term, the Ocoee, was introduced by Safford in his first report to designate certain very old, highly metamorphic rocks near the North Carolina line that have been assigned by the numerous geologists who have since studied them to practically all ages from Archean to Carboniferous, and the real age of at least the lower part is probably about as indeterminate now as it ever was.

The geological map accompanying the report was along the same general lines as the author's map of 1855, but shows much improvement in the working out of details. It has been reprinted many times by the Agricultural Department of the state and by the Industrial Bureau of the Nashville, Chattanooga & St. Louis Railway. It is still the only geological map of the state, though now more than forty years old.

Some of the plates originally contemplated for Safford's report were never published, as may be seen from the double designation, first by letters not in complete sequence and later by numbers, of the plates in the report as issued. Some additional illustrations had been prepared before the war stopped the work, and the writer has the only copy of the report he has ever seen with the panoramic views facing pages 40 and 66, described in footnotes on these pages, but lacking in the copies usually seen.

### The Decade From 1870 To 1880.

This decade saw a gradual resumption and extension of mining activities in the state. Most of the geological work of the period was in the shape of reports on mineral properties made for private parties, most of which were never published. No geological survey was maintained by the state, but the Bureau of Agriculture, under the guidance of Col. J. B. Killebrew, issued a number of reports setting forth the mineral resources of the State as we shall see presently, after noticing the earlier publications of other workers during the decade.

Worthen, in 1870, announced his belief that the upper Silurian of West Tennessee contained a mingling of Niagara and Lower Helderberg fossils and that the latter term should be dropped.

The next year Hilgard read before the American Association for the Advancement of Science, a paper on the geological history of the Gulf of Mexico, that was full of interesting and suggestive points, whether one agrees or not with his belief that the Gulf may have been isolated from the Atlantic during the whole or a part of the period between the

Vicksburg and the Champlain. His discussion of the loess and alluvium, and of general conditions in the Embayment region during the time just indicated was especially good. In 1879 Hilgard expressed his belief that the loess with which he was familiar in the Mississippi Valley, was of aqueous not aeolian origin.

A. WINCHELL

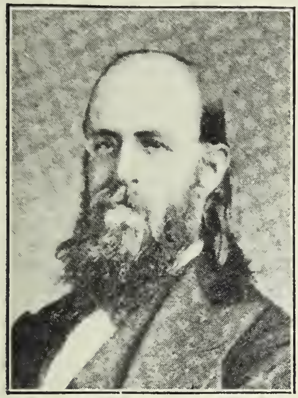
In 1871 Winchell assembled an imposing array of data on the correlation of the Marshall or Waverly group, and concluded that instead of being the equivalent of the Chemung it was later and of Sub-carboniferous age, and thought that the fossils from its base given him by Safford for study would prove to belong to the Kinderhook.

During the first half of this decade Lesley made a report for private parties on a number of tracts of land in the coal fields and in the eastern iron region. Some of these reports, such as the one on the Embree iron region, were published, others on coal areas that were not published are quoted from at some length by Killebrew as will be noted hereafter. In his article on a fault at Embree furnace, Lesley, describes the ores and the geology and structure and predicts that coke must soon replace charcoal in the furnace there. In another brief article he announces his recent discovery of a cross anticlinal axis in the Cumberland Mountain coal field of this state. Although he gives no hint as to its location, it must have been the one northwest of Careyville, as this is the only such anticline of any importance in the state. Safford must have also known of this anticlinal break, although he does not make the point quite clear in his report.

In 1873, Hunt, in an article on the copper of the Blue Ridge region, describes the Ducktown deposits as true veins posterior in origin to the inclosing schists, though usually conformable to the schistocity. Practically the same statements are repeated in his article on Ore Knob the next year.

In 1874, Wilcox called attention to the way many of the streams of the Southern Appalachians rise in the Blue Ridge and flow northwestward across the Great Smoky Mountains, which are much higher than the Blue Ridge, and concluded that the streams were older than the mountains and persisted in their course as the mountains rose.

In 1874 Bradley described from Cocke County a new type of granite containing epidote as a prominent constituent, and the next year announced his belief that the Ocoee and other highly metamorphic rocks along the North Carolina line were of Lower Silurian age, and had been subjected to metamorphosing mountain building forces in post-Carboniferous time. This view was embodied in 1875 in his geological chart of the United States, which shows practically all of East Tennessee as Lower Silurian. In his article explanatory of the chart he made the interesting suggestion that a large share of the drainage of East Tennessee may have gone directly southward to the Gulf by the Tallapoosa River system during the Champlain period.



F. H. BRADLEY

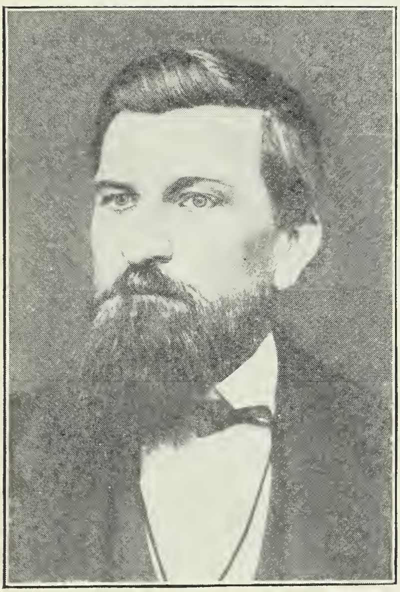
In 1874, Col. J. B. Killebrew first appeared as a contributor to the industrial and geological literature of the state in an imposing work of over 1200 closely printed pages, modestly styled an *Introduction to the Resources of Tennessee*. Doctor Safford was joint author and responsible for the geology of the work, which was confined to the economic materials of the state. These were discussed at some length, the articles devoted to certain minerals, especially the one on coal, containing much information as to the discovery and development of the deposits worked at various points in the state. The work was accompanied by Safford's geological map, published from the same stone as the 1869 edition, but with some new lettering overprinted relative to topographic, agricultural and mineral features.

Killebrew was then Secretary of the Bureau of Agriculture, but his title was soon changed to Commissioner of Agriculture, Statistics and Mines, and as such he issued in the next eight years a number of reports designed to encourage the development of the mineral resources of the state. In some cases he secured data for such reports by a brief trip of personal inspection, while in others he had to rely on replies to letters of inquiry or the published writing of Safford or others. Some of these reports contain sections, logs of wells, analyses, historic notes and other data of no little value.

In 1876 he prepared for distribution at the Centennial Exposition at Philadelphia a handbook on the agricultural and mineral wealth of the state in which especial attention was given to the iron ores, and the proximity of the ores, the coal and the flux were made prominent. In an appendix there are numerous analyses of iron ores. The book was ac-

companied by Safford's geological map, newly drawn, but not materially changed.

In 1877, he published in his report for 1876 a group of three geological articles the first of which described the Little Sequatchie coal field, including the Tracy City mines. The second was on the Ocoee and Hiwassie mineral district and was devoted chiefly to iron and copper. The third was on the mineral resources along the Cincinnati Southern and the Knoxville and Ohio railroads, and the country between. The coal mines and iron furnaces are described, and unpublished reports of Lesley on undeveloped coal areas in the northern part of the state are quoted at length. Each of these articles is copiously illustrated by maps.



J. B. KILLEBREW

In 1877 he issued a similar report on the oil regions of the state, and included it next year in his report for 1877 and 1878. This article sketches the history of the search for oil, and describes the activities among the oil men at that time. It is the fullest account of the early quest for oil that has been handed down to us.

The elements of the geology of the state having been included among the subjects to be taught in the public schools, McAdoo and White published an elementary textbook in 1875, which was followed in 1876 by Safford and Killebrew's elementary geology of the state. The revision of the latter book in 1900 included a brief account of the phosphates of the state and introduced some new formation names, and will be noticed on page 211.

In a general article on the iron industry, Newton, in 1875, briefly summarized conditions in Tennessee as they appeared to him. The Roane, Carter and Greene County regions in which there were ten furnaces all using charcoal as the chief fuel, he regarded as highly promising, but was not so confident of the future of the West Tennessee region with its fourteen charcoal furnaces.

In 1875 there was published the report of Lieutenant-Colonel Long on an examination of the Tennessee River from Knoxville to Chattanooga made in 1830, that in connection with subsequent descriptions of the same section of the river, especially that of 1893, is of especial value to the student of hydrographic problems.

In 1877, in their second report, the Board of Health of Nashville published a group of short articles on the topography, geology, water supply and climate of Nashville written by Foster, Safford, Lupton and Ford respectively, that give data of interest on the subjects included in the series. The third report contained an article by Winchell on the sanitary geology of Nashville in which he discussses the drainage and the character of the water from local springs and wells and from the Cumberland River.

THE DECADE FROM 1880 TO 1890.

In this decade most of the work sufficiently important to be noticed here was published by the State Board of Health in their monthly bulletins or by the State Department of Agriculture in its regular or special reports.

Killebrew, who had been much the most prolific writer of the preceding decade, published in 1881, a goodly sized volume on iron and coal that was compiled with the assistance of Henry S. Colton. In it are described the Unaka magnetites and limonites, the dyestone, the Cumberland Plateau carbonates, and the western limonites, and statistics for 1880 and analyses are given. In the coal section there is some discussion of the coal measures, but the chief part is devoted to a description of the producing mines. The work has numerous maps, and gives much general information on coal and iron.

Safford began an article on the relation of the geological and topographical features of the state to disease, in the first report of the state Board of Health, and discussed at some length the soil, drainage, water supply, climate and topography of the Unaka Mountain region. In the second report he discussed briefly the similar features of the Cumberland Plateau region, but as no further reports were published, the article was never completed.

Safford was employed by the Tenth Census to prepare a report on cotton growing in Tennessee and Kentucky, and in his report published in 1884 he gives a good topographic description of the entire state, followed by a special description of the topography, soil and climate of the cotton growing portion of the state. The soil map accompanying the report is essentially a geological one.

This census work supplemented by additional field work during several seasons, was the basis of several later reports. His report on agricultural geology in 1884 was essentially the Census report. His catalogue of mineral springs showed that in the Gulf embayment area of West Tennessee chalybeate springs prevailed. In the old hard rocks there and in Middle Tennessee they are sulphur; in the Cumberland Plateau they are chalybeate again, and in East Tennessee and the Unakas, where the rocks vary greatly, the springs are also quite varied. Essentially the same ideas occur in his 1889 articles on the same subject.

Safford's article on the upland formations of the counties along the Illinois Central Railroad from Memphis to Obion, gives a good idea of the loess and underlying Lafayette in that section.

This and all other work from 1880 to 1886 inclusive are summed up in his *Economic and Agricultural Geology of Tennessee,* where, in addition to the Memphis-Obion region, he describes the surficial geology along various other lines of railroad in West Tennessee, reports finding some lead at the Frazier mine in DeKalb County and some zinc at the Ewing mine in Wilson County, and discusses the agricultural geology of the state, especially with reference to cotton culture.

We learn from him also that U. S. Coast Survey work had been begun in 1876 in Tennessee by Professor Buchanan, of Lebanon, who measured a base there and had extended from it a system of triangulation to connect Nashville and Knoxville, and was then working southward from Knoxville to connect with work in Georgia. The latitude and longitude of a number of points had also been determined.

In 1889, Safford rendered to the Legislature a report of the work done in 1887 and 1888, in which he mentions briefly some work on iron ore, petroleum, clay and granite, and then devotes the main part of the report to the coals of Fentress, Overton and Morgan counties, which had been examined by him for private parties. He describes two areas of considerable size of sub-conglomerate coal 3 to 5 feet thick, separated by a belt in which coal is absent or too thin to work.

Colton, then inspector of mines, was, next to Safford, the most important contributor during this decade. His report on the coal mines of the state in 1883, gives much information as to both the geology and the development of the coal region, and in his article in 1885 on the upper coal measures of the state, he gives the fullest account that has so far been published of the Coal Creek-Careyville and the Elk Valley regions. He named the highest peak near Careyville Mt. Safford and gives a section showing the principal coals found in it.

The reports made by Jungerman and Guild as mine inspectors are confined largely to statements of the conditions found at the various mines, and give little of geological value.

In 1882, Hawkins published an official handbook of the state that has some notes of interest by Walter Allin on the coal lands and mines along the Cincinnati Southern railroad.

In 1888, the Department of Agriculture issued a new edition of Safford's geological map of the state published from a new plate that has been used for all subsequent editions, the more recent ones of which show the phosphate deposits by an overprint.

Beside the above, which were of more or less official nature, there were

numerous unofficial articles that deserve a brief word, and numerous others either too remote in their reference to Tennessee or so purely compilations from Safford or others that they add nothing to our knowledge and are entirely omitted.

Little, in 1881, quoted extensively the opinions of others on the blue clay of the Mississippi River and concluded that the bed and banks of the river were not of Port Hudson clay, but are recent sands and clays of alluvial origin. Gilmore adds in the next year's report of the Mississippi River Commission data as to levels, profiles and logs of boreholes from Cairo to Memphis that are of value to the hydrographer and geologist studying river activities and flood plain features.

In 1883, Davis called attention to the Tennessee River leaving the Great Valley at Chattanooga and cutting westward across the mountains, and from a study of the relation between faults and streams in that valley region points out that where a stream crosses to the upthrow side of a fault, as many East Tennessee streams do, the fault must have been of slow growth.

Elliott, in 1883, regarded the Great Smokies as the western edge of a great synclinal trough floored by Ocoee strata and having the Blue Ridge for its eastern edge, and considered it of Lower Silurian age or later.

Hunt, in an article in 1883 on the decay of rocks, pointed to the great decay in the rocks of the Appalachian Valley, and referred to the limonities there as having weathered from pyrite or siderite.

In 1884, in the reports of the tenth census, Willis published brief notes descriptive of some 83 localities in northeastern Tennessee in which he had seen deposits of iron ores. Most of these were limonite, and many analyses are given. Chauvenet gives similar notes on the Rockwood-Chattanooga Clinton ore region and on the western limonite region with historic references to the furnaces in the latter belt. The building stone article in these same reports by Colton and Gattinger is brief, and is confined almost entirely to the marbles.

Walcott, in 1884, regarded the Knox shale and sandstone as of Potsdam age and the Chilhowee and Ocoee as probably Lower Cambrian.

In 1885 there was published a second edition of Hermany's report on the Memphis Water Supply, originally made in 1868. He describes three proposed sources, Wolf River, Hatchie Lake and the Mississippi.

In 1886 another Memphis water report, by Hampton, was published. It was unfavorable to artesian wells and to Horn Lake and favorable to Wolf River as a proposed source.

Bowron, in 1886, in writing of the Sequatchie region regarded the Clinton red ore as due to the replacement, after being uncovered by erosion, of limestone by iron leached by surface waters from the Devonian

black shale exposed close above the Clinton, which retained much of its limestone where crossed and protected by stream channels.

Fleming, in 1887, described the physical and chemical character of red hematite ores used at Chattanooga, and gave analyses and cost of production of iron there then, and in the same year McCreath and d'Invilliers gave analyses of the ores and cokes used in the Chattanooga-Rockwood iron region with observations as to the quality and supply, and finally Porter, also in 1887, described the occurrence of the ores in both the eastern and western iron belts with many analyses of the ores from all parts of the state, and of the cokes used at the furnaces, and of the iron produced.

In 1888, Ulrich began in the *American Geologist* a somewhat elaborate article on the correlation of the Lower Silurian of Tennessee with other regions, and gave some lengthy lists of fossils, but never finished the article. In connection with his work on the Minnesota Survey the same problem was discussed at length by Winchell and Ulrich* in 1807.

## The Decade From 1890 To 1900.

This decade was marked by a greater increase in our knowledge of Tennessee geology than during any preceding decade save that from 1850 to 1860. The prominent events of the decade were the discovery of phosphate and the geological work of the United States Survey. The contribution made by the state was small, as Safford had no funds with which to work, and the Department of Agriculture and Bureau of Mines could do but little to help.

In 1890, Safford, in an article on the Memphis water supply in the bulletin of the Board of Health, described the general geology and under ground water conditions of the Memphis region, and gave the local section to the bottom of the 1165 foot well. He later wrote brief articles on the water supplies of Nashville, Erin and Sewanee.

In the volume on Mineral Resources in 1892, he divided the Tennessee coal field into a sub-conglomerate series best developed in Fentress and adjoining counties, a middle series lying between the conglomerate and the Emory sandstone with the Sewanee as the prominent coal, and an upper series found only in the northeastern part of the state with the Coal Creek coal as it most prominent member.

In the February, 1894, number of the *American Geologist*, he described and gave the geological position of the newly found blue phosphate just beneath the Devonian black shale, and the nodular phosphate in the green sand just above the black shale. In the *Engineering and Mining Journal* of April 21, 1894, he published another brief description of it, and on

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November 17, read before a farmers' institute in Columbia another paper that was published in the *Agricultural Report* in 1895. In it he refers to a lean phosphate in the Trenton at Totty's Bend—a forerunner of the discovery late in 1895 of the brown phosphate at that horizon at Mt. Pleasant—a discovery which he announced in the *American Geologist* for October, 1896. He recognized it as the leached residuum of a richly phosphatic limestone, the origin of whose phosphatic content was puzzling.

Aside from the above economic work, Safford gave the name, Middleton formation, to the basal Eocene as found with its green sand and marine shells near Middleton. He published a note on some bones of megalonyx said to have been found in 1884 in Big Bone Cave, and with Schuchert in 1899, described the Camden chert with its fauna of Lower Oriskany age.

The reports of the State Bureau of Mines, though chiefly devoted to routine descriptions of the condition of the mines, have occasional articles worthy of brief notice.

A special report by Ford, in 1891—probably afterward counted the first report of the Bureau of Mines—is devoted to the trouble at Coal Creek caused by the presence of convicts in the mines there. The fourth report, besides Safford's article on phosphate, contained one by Hayes, describing the blue, the nodular and the white phosphate, the latter being either a recent surface deposit about broken chert forming a breccia or a lean bedded deposit in the Ft. Payne, replacing limestone. In the fifth report there are some good historical notes on the marble industry, a note on petroleum, and an article by Brown on the geology and quality of the phosphate deposits. The sixth report contains another article on phosphate by Brown in which the Mt. Pleasant brown rock is described. In the seventh report Ormsbee, in an article on the rise and progress of coal mining in the state, in ignorance of the very early work mentioned by Kain in 1819, and by Troost in 1833, attributes the first commercial mining to H. H. Wiley on Indian Fork of Poplar Creek in 1847. He hauled coal some three miles to water and shipped it by flat boats to Huntsville and other points down the Tennessee River. Other small banks were soon opened for local use, but the first extensive mining resulted from the building of the Nashville and Chattanooga Railroad in 1854. The report gives a brief sketch of copper mining and a note on oil, with a list of borings. Several succeeding reports contain short articles on phosphates.

The most important work of the U. S. Geological Survey was the publication of areal geological maps accompanying folios covering the larger part of the Cumberland Plateau and of East Tennessee. Most of these

maps were made during the early days of the Survey, when its standards of work, both topographic and geologic, were not so high as now and when the methods of investigation were less refined and accurate. At that time attention was more largely devoted to the general geology, the regional structure, the characters of the formations and the geological history of the region, rather than to the detailed descriptions and economic study of the mineral resources.

This mapping in the coal field, though regarded as high grade at the time is outdistanced by the rapidly expanding development and improved methods of current economic treatment so that it now needs revision on a larger and more detailed scale. This task the United States Geological Survey, in coöperation with the State Survey, has already begun. The new work is on the scale of one mile to the inch with 20-foot contours, and leaves nothing to be desired either as to topography or geology.

The members of the U. S. Geological Survey, who did most work in Tennessee during the decade were Hayes, Keith, Campbell, Walcott and McGee.

Of these Hayes was engaged in studying structural and physiographic problems in the Chattanooga region, and wrote in 1891 an article describing the overthrust faults of the Southern Appalachians. In it he seemed inclined to accept the Silurian age of the Ocoee from the work of Willis and Keith. In 1894 he published with Campbell, an article on the Geomorphology of the Southern Appalachians, in which the attempt is made to solve some of the larger physiographic problems of the region by applying a theory of broad uplift at certain periods with conspicuous warping and resultant stream readjustment. The most daring portion is the theory of the diversion of the Tennessee River near Chattanooga from a former course along the Great Valley to the Coosa to a new course across the Walden Ridge part of the Cumberland Mountains. In 1899 Hayes returns to the same general study in his article on the physiography of the Chattanooga district, in which an excellent description is given of the topography, stratigraphy and structure. The physiographic history is sketched in much detail, and his faith in the diversion of the Tennessee at Chattanooga is reaffirmed.

Meantime Hayes had become interested in the study of the phosphate, and for several years made detailed studies of the blue, the white and the brown rock fields, and wrote a number of articles describing the geology, mode of origin, distribution and development of the deposits. The first of these is a brief note in the Fourth Report of the State Bureau of Mines in 1895. A much more comprehensive account is given the same year in the Sixteenth Annual Report of the U. S. Geological

Survey. After stating and rejecting various possible theories of origin for the blue and nodular rock—the only kinds that had then been discovered—he favored the accumulation of the blue (then often called black), rock by phosphate-secreting organisms, followed by a period of black shale deposition which he thought was ended by a widespread volcanic eruption, the ejected ash forming the blue shale, with the nodular phosphate at the top of the black shale. He was led to this ashbed idea by Wolff examining microscopically a specimen of a similar material from Arkansas and thinking it was composed partly of volcanic ash. More careful examination soon exploded the volcanic theory by leading him to recognize the blue, or often green, shale as largely glauconite instead of volcanic ash, as may be seen from his report in the Seventeenth Annual Report. His phosphate article in the Twentieth Annual is confined largely to the brown phosphate, and he outlines the conditions favorable for the accumulation of a phosphatic limestone and for the subsequent removal of the lime by leaching.

Keith, in 1892, described the structure of Chilhowee Mountain and concluded that Appalachian folding and faulting began in early instead of late Paleozoic. In his article on some stages of Appalachian erosion he opposed the theory of broad deformation or warping, and believed that seven periods of approximate reduction can be distinguished in this region, the successive uplifts being broad and uniform, with only local and very subordinate zones of pronounced warping.

For some years McGee had been studying the surficial formations of sand and gravel on the Atlantic coastal plain, and had extended his studies westward into the Gulf Embayment region, announcing in 1890 that he had traced his Appomattox (now Lafayette) formation into northern Mississippi and considered it the same as Hilgard's Orange sand, or Safford's LaGrange. The same year he read a paper at the meeting of the American Association for the Advancement of Science in which he stated his belief that the Columbia formation reaches a thickness of several hundred feet in the Mississippi embayment, and is divisible into a brown loam, a loess, a sand and gravel, and the Port Hudson. It is possible that the sand and gravel to which he refers belongs to an older formation, and that the relation of the Port Hudson to the Columbia, if not in fact its existence as a formation distinct from the alluvium of the Mississippi, may well be called in question.

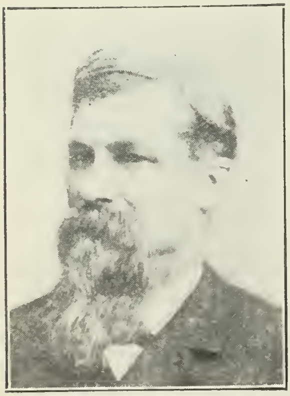
McGee's Appomattox having been correlated with Hilgard's Orange sand, and the varying usage of the latter term having led to its abandonment and the substitution of the term Lafayette, McGee's report, which appeared in 1892 was entitled "The Lafayette Formation." It was a paper of daring sweep and marked an epoch in coastal plain investiga-

tion in that it coördinated much that had previously been neglected or regarded as unrelated. As is usual in daring generalizations, however much of truth there be, some error is apt to creep in, hence it is not surprising that McGee's interpretation of the Lafayette in West Tennessee is not fully accepted today. At LaGrange, for instance, he made the Lafayette 200 feet or more in thickness, and considered it tripartite, when it is only about a score of feet, or less, in thickness, and the two supposed lower divisions of it there really belong to the LaGrange formation, and are much older than the Lafayette.

Walcott's studies of the Cambrian led him in 1890 to correlate the Calciferous with the Knox dolomite, and to announce in the Tenth Annual Report that the only place in the Southern Appalachians where the Lower Cambrian had been identified was in Chilhowee Mountain. In 1891 in his Bulletin on Cambrian correlation he gave a good summary of the views that had been held as to the Cambrian in Tennessee. He regarded the Knox shale and the lower part of the Knox dolomite as Cambrian, and considered the Ocoee as Silurian. In 1892, in the *American Journal of Science*, he announced that typical lower and middle Cambrian faunas had been found at a number of points in East Tennessee, and that the lower 2,000 feet of the Knox dolomite was of Upper Cambrian age. In 1894 he describes in the lower part of the Ocoee a conglomerate, with boulders several feet in maximum diameter, and in accounting for their origin he suggests that they may be boulders broken by shore ice from ridges or domes that had recently been raised from the sea bottom, thus pointing to possible folding movements in Ocoee time.

The Devonian and Mississippian correlation paper by Williams gives little of value as to Tennessee, as the Tennessee portion is brief and was based on a study of the literature only.

Gannett published data as to geographic positions and triangulation work in the state.



T. C. CHAMBERLIN

Chamberlin * regarded the Orange sand (Lafayette) as preglacial in age, and considered that the loess was deposited in the early glacial period; that in the succeeding interglacial epoch the great trench in which the Mississippi bottoms now lie, was eroded 40 to 60 miles wide and several hundred feet deep, and that in the later glacial epoch this trench was filled to the extent we find it today.

In an article in 1891 Chamberlin and Salisbury discuss the relation of the loess to glacial phenomena and to the underlying gravel (Lafayette) and conclude that the latter is pre-Pleistocene, and that the loess is bipartite and

belongs to the two episodes of the first glacial epoch as then interpreted by them.

A pamphlet, published by the East Tennessee Land Company in 1891, contained reports by Bryant, Roberts, Safford, Guild and Koenig on the coal and iron properties of the company. Numerous measured sections and analyses of coals and iron ores are given.

In 1891 Hilgard gave a history of the use of the term Orange sand, and in a brief note on the Lafayette in the Mississippi Valley regarded it as of fluvial origin, with uplift to a grade that would place the northern part of the Mississippi basin 3,000 feet higher than now. The next year he returned to the problem with an excellent article on the age and origin of the Lafayette. He considered it due to broad shallow floods from the north during a period of elevation, and was inclined to place it in the epoch of early glacial melting, instead of in pre-glacial time. He gave very clearly the relationship of the Lafayette to the other formations of the Mississippi embayment, and regarded all of the lower, plant-bearing phases of the Lafayette as conceived by McGee as not really belonging to the Lafayette.

The decade under consideration was marked by especial activity along physiographic lines. An addition to the work of Campbell, Hayes, Keith and others, an article by Davis on the geological date of the origin of certain topographic forms deserves especial mention. He regarded the Cumberland Plateau as a peneplain of Cretaceous age, and the lower peneplain in the Great Valley of East Tennessee as of Tertiary age. These determinations have been generally accepted by those who have worked in this Appalachian region, although when attempts have been made to prove the age of these peneplains the results have always appealed to the present writer as being inconclusive.

Hull, in 1891, after a personal inspection, described the topography of the Chattanooga region, and reached the interesting conclusion that the Tennessee River has persisted in its initial course through the mountains.

In addition to the papers on phosphates by Safford and Hayes already noticed, Meadows and Brown, in 1895, published a good account of the Devonian phosphates in which the history of their discovery and the geography, geology and economic features of the deposits were discussed. Brown contributed, as already noted, articles on phosphates to the fifth, sixth and seventh reports of the Bureau of Mines, and one to the Nineteenth Annual Report of the U. S. Geological Survey, describing especially the Mt. Pleasant, or brown rock, field, but including notes on other fields.

**Geo. Soc. Amer., Bull.,* Vol. 1, pp. 469-474, 1890.

In 1896, Miller called attention to the presence of many casts of the minute gasteropod, cylora, in the phosphate, and to the fact that the shells of this fossil are richly phosphatic.

Henrich, in 1896, published an article on the Ducktown copper region, giving a comprehensive account of the discovery and past developments, of the structure of the deposits, and the character and genesis of the ores. He believed the ores were deposited by hot waters ascending along fault fissures and replacing pyroxenic rock probably in the form of an eruptive dyke, and that the process of replacement was completed later by the introduction of sphalerite, galena, quartz, marcasite and pyrite.

Schmitz, in 1896, in an article on petroleum, gave a good description of conditions in the Obey River and Rugby regions with logs of Bob's Bar, the Stone 1, 2 and 3 and the MacDonald wells.

In 1897, Johnson published an article on the iron ores of the Embree property, the furnace practice, and the quality of the output.

Vanderford, in 1898, published the results of the most extensive piece of soil work yet undertaken in the state. He described the soils of the state by geological provinces, thus emphasizing the close connection between the soil and geology, and gave many chemical and mechanical analyses of the various soil types with notes on the physical character, crops and climate, and accompanied the report by a soil map of the state.

In 1898, Lundie gave a good account of past effort to obtain a satisfactory water supply for Memphis, and described the artesian system then in use.

Crook published, in 1899, a work on the mineral waters of the United States that gives probably the best scientific description extant of the mineral springs of the state.

In addition to the paleontologic work of Safford, Schuchert, and Walcott, Brown listed and described the coal measure plants found at Tracy City. Jones, in his *Geology of Nashville,* gave the fullest list of local fossils that has so far been published. Miller described in a series of articles a considerable number of new crinoids from the state. Rauff described and figured numerous Tennessee sponges, and Head published a list of fossil sponges that contains numerous Tennessee species.

### The Decade From 1900 To 1910.

The chief events of this decade were the development of the phosphate industry, the beginning of modern detailed coal work and the establishment of the present geological survey.

The beginning of the decade witnessed the last work of Safford, who

for fifty years had been the most active single figure in geological work in the state.

Safford and Killebrew, in 1900, revised their text-book on Tennessee geology, including in it an account of the phosphate discoveries, and giving a new classification by Safford of Tennessee geological formations that included a few new formation names .

The material in this text on the horizons of phosphate rock was summarized by Safford in 1901 in the *Bulletin of the Geological Society of America*, and in the same volume he reproduced his new table of Tennessee formations with definitions and comments on the usage of certain of the terms and notes on various matters of priority of usage and age of certain formations.

The ninth report of the State Bureau of Mines contains a short article by Ruhm outlining the development in the phosphate fields, and the same author describes in the *Engineering and Mining Journal*, the unsatisfactory condition of the phosphate industry in 1907 on account of low prices.

The report of the State Department of Agriculture published in 1901, contains an article by Hayes that gives a good general description of the brown, blue and white phosphate rock, with their mode of occurrence and relation to the topography, and in the 1903-4 report Ruhm gives a good sketch of the discovery and development of the phosphate deposits. The handbook issued by the Department in 1903, contains brief articles on coal and iron by Shook, phosphate by Hayes, and clay by Brown, but the state did no distinctly geological work during the decade.

## Work of the United States Geological Survey.

Most of the serious geological work of the decade was done by the Federal Survey, and included detailed areal mapping, a study of the phosphate, of the underground waters of the western part of the state, and of various other economical resources and scientific problems.

Hayes continued his phosphate work, publishing in the Twenty-first Annual Report a paper on the character, occurrence and origin of the Perry County white phosphate, and in 1903 a further paper on its origin and extent.

In 1902, Hayes gave a good brief summary of both the geological and economic features of the Southern Appalachian coal field, and in 1903, along with Ulrich, published a geological folio of the Columbia-Mt. Pleasant region in which the phosphates are the prominent economic feature, and the finger-like embayments of limestone that must have formed quite up to the shore line of very narrow bodies of water, are

the prominent scientific feature. Hayes, in 1909, estimates the iron ore reserves for the various districts of Tennessee.

Keith, in 1903, gives, in an article on the ores of the Cranberry district, a brief note on some brown hematite in the neighboring part of Tennessee, and in the same year gives a resume of the information on marbles gathered during folio work in East Tennessee. In 1904 he discusses the character and occurrence of overthrust faulting in the Southern Appalachians, and describes recent zinc mining in East Tennessee, describing the Holston deposit as a brecciated zone that extends for forty miles and probably contains a large amount of ore.

In 1901 Eckel notes the occurrence of the newly found white phosphates of Decatur County, and in 1903, describes them as promising deposits. This same year he gives as the result of a hurried trip, brief notes descriptive of the lenticular clay deposits of the LaGrange formation from Grand Junction to Paris, and in 1906, calls attention to the suitability and advantageous situation of the limestone and shale in the Cumberland Gap region for cement making.

Ulrich in 1905, points out briefly the more prominent localities in East and Middle Tennessee, where limestone and shale, probably suitable for cement manufacture, are to be found.

Weed, in 1901, in his article on types of copper deposits in the Southern states, gives a succinct description of the Ducktown deposits, using them as the type of deposits consisting of pyrrhotite veins filling fissures, and representing the replacement of a zone of sheeted rock, and in 1903, 1905, and 1906, gives other brief references to the same deposits.

Gannett, from 1901 to 1907, published in various bulletins of the Federal Survey data pertaining to Tennessee boundaries, river profiles, triangulation stations, and elevations, the details of which need not be given here.

Ries, in 1903, gives a few brief notes on the clays of West Tennessee, largely or entirely compiled and containing practically nothing new, and in 1906, Crider gives the result of a brief study of the same clays in which he gives sections of the clay deposits and describes their character and uses.

Glenn, in 1904, describes the geology of the Gulf embayment area of West Tennessee, with especial reference to the occurrence of underground waters, and describes the character and probability of obtaining such waters in that region.

Ashley and Glenn, in 1906, describe in detail the coals of the Cumberland Gap region, the southern or Bennett Fork end of which extends

over into Tennessee. They show the existence there of over a dozen different coals of workable thickness, more than three fourths of which are now being mined. They give detailed sections of the little known northeastern part of the Tennessee coal field.

In 1908 Holmes publishes the results of exhaustive texts of coals from Fork Ridge, Gatliff, Oliver Springs, Petros, Waldensia, Clifty, Coalmont, Orme and Ozone.

Burchard, in 1907, shows the advantages of the soft variety of Clinton red iron ore for making metallic paint, and describes the deposit and the working in White Oak Mountain near Ooltewah, where most of that produced in the Chattanooga region is obtained. In 1909, he published an estimate of the tonnage of Clinton ore by districts in East Tennessee, giving for each of the several districts the detailed data on which such estimate is based. He considers the amount available at present as nearly 50,000,000 tons, and the reserve tonnage as somewhat greater than that at present available.

Phalen, in 1907, gives a brief description of the bauxite deposits that had recently been opened on the southeastern slope of Missionary Ridge.

In addition to the considerable variety of economic work by the Federal Survey thus briefly outlined, it also published in this decade, detailed geological maps and descriptions of the Maynardville, Cranberry, Asheville, Mt. Mitchell and Roane Mountain areas, that show a marked advance over the early folio work of the preceding decade.

Along more purely scientific lines, though having also its economic bearing, is the work of Van Hise and Leith on the pre-Cambrian, published in 1909. In the section devoted to Tennessee they summarize the work and views of Troost, Owen, Currey, Safford, Bradley, Keith and Hayes. The age of Safford's Ocoee series furnishes the chief problem for this region. Safford at first regarded it as of Potsdam, or early Cambrian age, but at the last regarded it as pre-Cambrian. Bradley thought it probably Silurian. Keith mapped it in 1895 as of unknown age, but later, with much fuller detailed study, regarded it as all of Cambrian age. Hayes, in 1895, thought it probably Algonkian. Van Hise and Leith think the upper half of it is Cambrian and the lowed half probably Algonkian. The age of the Ocoee has been one of the most studied and most puzzling problems in American geology, and while much progress has been made toward its solution, it can not yet be said to be fully solved.

Pate and Bassler, in 1908, give the results of a study of the stratigraphy and rich fauna of the Niagara strata of the glades of Decatur, Perry, Hardin and Wayne counties and propose an emended division of the Niagara rocks of that region.

The Smithsonian Institution published, in 1909, a critical summary of Troost's monograph on crinoids, prepared by Miss Wood. The history of this monograph is given by Miss Wood, and has also been given in recent years by Schuchert [1] and by Glenn.[2] Very briefly, the monograph was accepted by the Smithsonian Institution shortly before Troost's death in 1850, and with 317 specimens representing the 108 new species described, was put in James Hall's hands for revision before publication. He sent them to Agassiz, who, after five years, returned them untouched to Hall, and both manuscript and specimens remained in Hall's possession for more than forty years, and only after his death were they returned to the Smithsonian. Meanwhile Hall described from time to time, over his own name, first one and then another of Troost's genera and species as they came to his hands from other sources. Others, ignorant of the contents of Troost's unpublished work, occasionally ran across and described other species, so that only 39 of his 109 species can now be saved to Troost. Many of Troost's specimens were from White's Creek, near Nashville, and while they have long been known as list names, had never been described so as to establish their identity and priority until this publication appeared.

During the decade the Federal Bureau of Soils mapped and described the soils of the Davidson, Coffee, Giles, Grainger, Greeneville, Henderson, Lawrence, Montgomery, Overton, and Pikeville areas.

In 1902, President Roosevelt transmitted to Congress a report by the Secretary of Agriculture describing the relation forests bear to erosion, floods, and stream flow in the Southern Appalachians, and including special articles on topography and geology by Keith, hydrography by Pressly and Myers, and climate by Henry.

Page published the results of experiments with tar and oil for road building, made by Sam C. Lancaster, at Jackson, and Bauer and Faris give the variation in magnetic declination for different years.

### Work by Individuals.

In addition to the bulletin by Gannett on the boundaries of the state referred to on a preceding page, Garrett reprinted, in 1900, a report on the southern boundary of the state made to the Legislature in 1833, and in 1901, followed it with an article on the northern boundary of the state.

In 1901, Foerste published the first of a series of articles giving the results of a careful stratigraphic and faunal study of the Ordovician,

1. Schuchert, Charles, *Smithsonian Miscel. Coll., Quart.* Issue, Vol. 2, pp. 220 and 221, 1904.

2. Glenn, L. C., *Amer. Geol.,* Vol. 35, pp. 79-81, 1905, and *Vanderbilt Univ. Quarterly,* Vol. 10, pp. 275-279, 1910.

Silurian, and Devonian of West Tennessee. He established a number of new divisions of the rocks, discussed faunal relationships and concluded that the Cincinnati uplift began certainly in Silurian and probably in Ordovician time.

In addition to the report of Ashley and Glenn, a number of other articles on coal appeared during this decade. Duffield, in 1902, calls attention to the coals of Fentress and adjoining counties as undeveloped but highly promising. Evans gives some notes on Jellico coals, with a section showing the relative position of the better known coals of that field. Ferris gives the results of calorimetric tests of Jellico, LaFollette, Coal Creek and Oliver Springs coals. Pultz describes mining in the Cumberland Gap field, and Stevenson summarizes from the literature the broader facts first as to the sub-Carboniferous and later as to the Pottsville in Tennessee.

There are a number of articles on iron worthy of note. Maxwell describes, in 1904, a belt of brown ores in Carter and Johnson counties in which he claims there is a large amount of ore. Judd, in 1907, in an article on soft Clinton ore, calls attention to a deposit of such ore at Sweetwater; and Higgins, in 1909, describes the ore beds, limestone, and coal deposits, and the operations of the Roan Iron Company.

In phosphate, beside the articles already mentioned, Brown published, in 1904, an article on the phosphate deposits of the Southern States in which there is a good description of the various types found in Tennessee, with a history of their discovery, and a statement of their mode of occurrence, manner of mining and quality and the accepted theories of their origin. Other articles were written by Johnson on the origin and character of the phosphates, and by Memminger on their commercial development.

In copper, Kemp describes Ducktown topography and geology briefly, and gives a very full account of the mineralogy of the ore and the order of the formation of the ore and other minerals. He believes the ore to be a replacement of a zone of crushed country rock, though he recognizes certain facts indicating crystalline limestone as the material replaced. Higgins, in 1908, describes the method of mining and smelting the copper ore.

In lead and zinc, Watson describes the Powell River belt where both occur and the Holsten belt where the zinc occurs mostly alone. He regards the ores as concentrated from the limestone by underground waters in brecciated zones with much replacement but little or no secondary enrichment.

Barytes claims three papers in this decade. Judd describes it as occurring in lumps in the residual clays of the Knox dolomite, and gives notes on mining, cleaning, washing, bleaching, and grinding. Weller describes the vein of barytes on the French Broad River in Cocke County as occurring between sandstone and quartzite, being seven feet thick and traceable for three miles. Fay describes both modes of occurrence.

The character of the water supply of Nashville called for a number of papers. Walker, in 1904, describes the character of the Cumberland River basin, and believes that the proposed locks and dams will have no effect on the quality of the water, and Jackson describes filtration methods, with frequent reference to conditions pertinent to Nashville. In 1905, McDonald describes the Nashville filtering galleries, and Schuerman, after studying water purification investigations of other cities, concludes that thorough investigation is needed in Nashville before any comprehensive plan of purification is adopted. The same year Brown published the results of an inquiry into the quality of the water supply of Nashville, and showed that the death rate from typhoid and other enteric diseases was abnormally high, attributed it to contaminated springs and wells and impure river water, and urged the purification of the city supply and the closing of springs and wells.

In Memphis also, the water supply was a subject of investigation. Hider, Omberg and Bell describe the artesian system and its probable limitations, and makes estimates of the cost of utilizing the Mississippi as an ultimate source of supply.

Of general structural and faunal interest is the paper by Ulrich and Schuchert* on Paleozoic seas and barriers in eastern North America, in which they discuss at length the evidence for the existence in the Appalachian region in early Palezoic time of long narrow barriers separating equally long narrow troughs which, though adjacent and contemporaneous, received unlike sediments, and contained unlike faunas.

When one remembers that in his early reconnoissance in 1854, Safford quickly grasped this fact for the region from Virginia across East Tennessee and well down into Georgia, and clearly stated it in 1858, the following extract from Ulrich and Schuchert is somewhat refreshing:

"Though abundant corroborative evidence of the existence of a narrow barrier between the stratigraphically inharmonious areas is afforded by the structural geology of the region in question, it was perhaps scarcely to be expected that the geologists who attacked the problem chiefly or solely from that side would find the true solution. It required detailed paleonological knowledge, particularly as to assemblages of fos-

*Ulrich, E. O. and Schuchert, Charles, *Rept. N. Y. Paleontologist* for 1901, pp. 633-663, 1902.

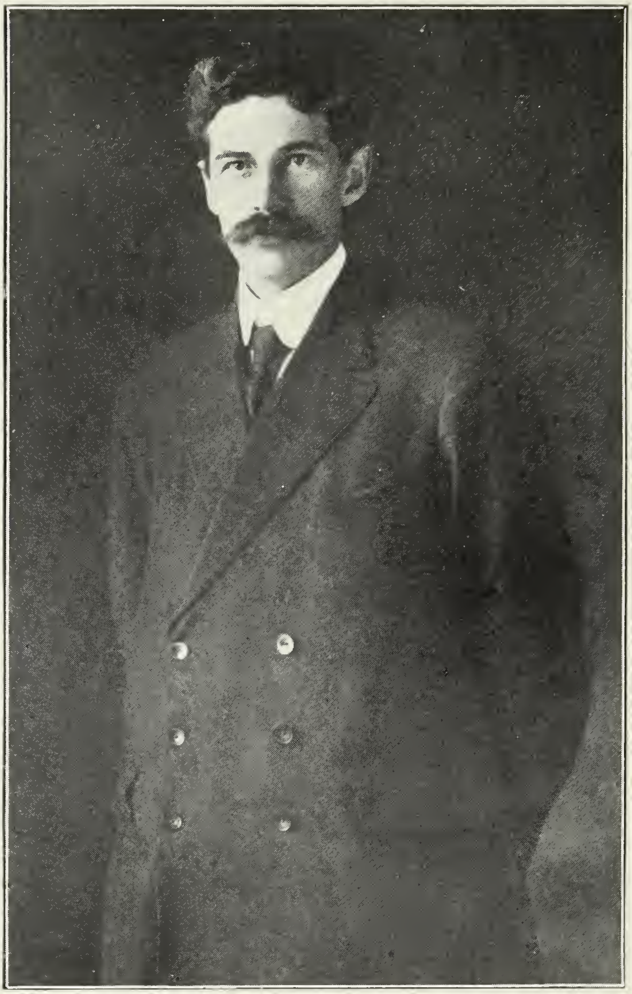
sils and their geographic distribution, before the faunal distinctions indicating separate provinces could be appreciated. Had the geologists engaged on Southern Appalachian problems received a suggestion from the palentologists of the striking dissimilarity marking the faunas pertaining to the lithological equally dissimilar Ordovicic rocks lying respectively on the east and west sides of the Great Valley, it is scarcely conceivable that they would have failed to grasp the leading facts in the case." The authors deserve credit for the array of facts they present, but if they had been familiar with the literature of their subject they would have spared themselves the writing of the above paragraph with its amusing assumptions.

Dabney, in discussing the geology of the Mississippi embayment, summarizes the opinions of previous workers and dissents from Little's conclusion that the river flows essentially in alluvium. He believes that the alluvium is relatively insignificant in quantity, and that the great bulk of the valley filling is Port Hudson blue clay. He believes also that restriction by levees will not cause deposition in, and filling of, the river channel.

In physiography, White criticises the view that the Tennessee near Chattanooga once continued southward to the Coosa, as Hayes and Campbell believed, and as was held—as White points out—as far back as 1830 by Lieut.-Col. S. H. Long. He believes rather that up to the close of the Cretaceous the rivers draining the Great Smokies and the Valley of East Tennessee all flowed off to the northwest and that after the uplift at the close of the Cretaceous the Tennessee captured the more northern ones and alone maintained its course.

In 1905, Johnson, writing on the same problem of the Tertiary history of the Tennessee River, states the problem, summarizes the literature on both sides and concludes that the river has persisted in its present course probably at least since the close of the Cretaceous.

In the reports of the Army Engineers from 1868 down to date, there are many articles descriptive of the larger streams of the state. Many of these are mainly routine reports on the work of improvement from year to year, but they often contain also valuable information as to the character of the river and the changes that may be occurring in it. Others are very detailed reports of examinations and surveys, generally accompanied with detailed maps. Such reports are of great value to the geologist, meteorologist, or engineer interested in hydrographic problems. They are so numerous, so special in their nature, have been indexed so fully by the Army Engineers and listed at such length in Miss Cockrill's bibliography, that it is not deemed necessary to take the space here that would be required to present them with such fullness as would make the presentation worth while.



GEO. H. ASHLEY,
Third State Geologist

It has further been thought best to end this summary with the close of the decade from 1900 to 1910. The most important event of the decade was the establishment of a new state survey by the Legislature of 1909. The history of this movement has been given by Ashley in *Bulletin* 1-*A*, of the publications of the present survey, and need not be repeated here. The work of the present survey is rapidly making its own best record in its bulletins and monthly journal, and a recent number of the latter has recorded the resignation of Doctor Ashley, and the appointment of Mr. A. H. Purdue as State Geologist.

April 15, 1912.

# NEW PUBLICATIONS

## TO PUBLISHERS OF NEWSPAPERS, MAGAZINES AND TECHNICAL JOURNALS:

**There are over 2,000,000 people in Tennessee, and some outside. As only 3,000 copies of the Survey's publications are printed, it is realized that if the people of the state, and outside of the state, are to be benefited in any large measure from the work of the Survey, it must be through the co-operation of the newspapers, magazines, and technical journals. Therefore the statements of the results of the Survey's work and reviews of its new publications are cast in form suitable for use by publishers in the hope that they will co-operate in extending the benefits of the Survey's studies by making liberal use of any or all of the matter in this journal.**

### TENNESSEE A LEADER IN GEOLOGIC WORK.

That Tennessee was the first state or country to persistently maintain for any considerable time an official geological survey, is known to few, but such is the case. This Survey was the one headed by Troost, which was established December, 1831, and continued for twenty years.

Even before that time many articles had been written regarding the geology of Tennessee by scientific travelers through this region, and before the end of the eighteenth century many small iron forges were in operation in East Tennessee.

The Troost Survey was followed by that of Safford in 1854, which lasted for a number of years after the Civil War. In 1869, Safford published a volume on the *Geology of Tennessee,* which excels any similar sized volume on the geology of any state, written either at that time or since.

The present Survey was established in 1909, several years after Safford's death, and immediately took a leading place among the surveys of the country in its new and aggressive methods of getting the results of its work before the public.

The history of these events, as well as of all the geological work that has been carried on in Tennessee up to 1910, is admirably presented in a paper on "*The Growth of Our Knowledge of Tennessee Geology,*" by L. C. Glenn, which appeared in the May issue of *The Resources of Tennessee,* published by the Tennessee Geological Survey.

## NEWS NOTES IN AND OUT OF THE SURVEY.

The State Geologist has returned from New Orleans, where he attended the National Drainage Congress, as a delegate from Tennessee. The Congress was in session April 10-13, and during this time reports were given on drainage work in all the states.

The Southern Commercial Congress held its 4th annual session in Nashville on April 8, 9, 10 at which time delegates from all the Southern states were in attendance. The program as a whole was intended to define the South's educational and agricultural recovery.

One of the principal guests of the Congress on this occasion was Milton Whitney, Chief of the Bureau of Soils, Department of Agriculture, who delivered an interesting talk on "The Soil Resources of the Southern States."

J. G. Peters, Chief of Coöperation of the Forest Service, was a delegate to the Congress and gave talks on forestry in the South.

The Survey has recently received a nearly complete set of the Smithsonian reports and many other scientific works from the library of Capt. R. D. Smith, of Columbia, Tenn. The books will be quite an addition to the geological library, and proper appreciation for them is hereby expressed.

Mr. Wilbur A. Nelson has done some field work during the month on the coals of Hamilton and Rhea counties.

The Tennessee Academy of Science held its first general meeting at the Carnegie Library on April 6, at which time the following officers were elected: C. H. Gordon, President, University of Tennessee, Knoxville; J. I. D. Hinds, Vice President, Cumberland University, Lebanon; Wilbur A. Nelson, Secretary, Capitol Annex, Nashville; S. M. Barton, Treasurer, University of the South, Sewanee, and E. S. Reynolds, Editor, University of Tennessee, Knoxville. The success of the Academy was assured by very fine attendance at this, the first meeting, and many interesting papers were given. The next meeting will be held in Knoxville, on the Friday after Thanksgiving (November 29).

Mr. Robert Dismukes has been busy during the month preparing maps and sketches to accompany Mr. Purdue's bulletin on zinc, to appear shortly.

## Publications of Geological Survey of Tennessee Issued.

The following publications have been issued by the present Survey, and will be sent on request *when accompanied by the necessary postage.* To make it possible for libraries to complete their sets, and for persons having real need for any of the volumes to obtain the earlier ones at small cost, 500 copies of each report are reserved for sale, at the cost of printing; the receipts from the sales being turned into the State Treasury.

Gaps in the series of numbers are of reports still in preparation:

**Bulletin No.** 1—Geological Work in Tennessee.

A. The establishment, purpose, object and methods of the State Geological Survey; by George H. Ashley, 33 pages, issued July, 1910; postage, 2 cents.

B. Bibliography of Tennessee Geology and Related Subjects; by Elizabeth Cockrill, 119 pages; postage, 3 cents.

**Bulletin No.** 2—Preliminary Papers on the Mineral Resources of Tennessee, by George H. Ashley and others.

A. Outline Introduction to the Mineral Resources of Tennessee, by George H. Ashley, issued September 10, 1910; 65 pages; postage, 2 cents.

D. The Marble of East Tennessee, by C. H. Gordon; issued May, 1911; 33 pages; postage, 2 cents.

E. Oil Development in Tennessee, by M. J. Munn, issued January, 1911; 46 pages; postage, 2 cents.

G. The Zinc Deposits of Tennessee, by S. W. Osgood; issued October, 1910; 16 pages; postage, 1 cent.

**Bulletin No.** 3—Drainage Reclamation in Tennessee; 74 pages, issued July, 1910; postage, 3 cents.

A. Drainage Problems in Tennessee, by George H. Ashley; pages 1-15; postage, 1 cent.

B. Drainage of Rivers in Gibson County, Tennessee, by A. E. Morgan and S. H. McCrory; pages 17-43; postage, 1 cent.

C. The Drainage Law of Tennessee; pages 45-74; postage, 1 cent.

**Bulletin No.** 4—Administrative Report of the State Geologist, 1910; issued March, 1911; postage, 2 cents.

**Bulletin No.** 5—Clays of West Tennessee, by Wilbur A. Nelson; issued April, 1911; postage, 4 cents.

**Bulletin No.** 9—Economic Geology of the Dayton-Pikeville Region, by W. C. Phalen, for sale only, price 15 cents.

**Bulletin No.** 10—Studies of the Forests of Tennessee.

A. An Investigation of the Forest Conditions in Tennessee, by R. Clifford Hall; issued April, 1911; 56 pages; postage, 3 cents.

B. Chestnut in Tennessee, by W. W. Ashe, issued December, 1911; postage, 2 cents.

**Bulletin No. 13**—A Brief Summary of the Resources of Tennessee, by Geo. H. Ashley; issued May, 1911; 40 pages; postage, 2 cents.

**"The Resources of Tennessee**—A monthly magazine, devoted to the description, conservation and development of the State's resources. Postage, 2 cents a number.

PRINCIPAL PAPERS.

Vol. I. No. 1—The utilization of the small water powers in Tennessee, by J. A. Switzer and Geo. H. Ashley.

No. 2—The Camden chert—an ideal road material, by George H. Ashley.
The Fernvale iron ore deposit of Davidson County, by W. A. Nelson.
Cement materials in Tennessee, by C. H. Gordon.

No. 3—The gold field of Coker Creek, by Geo. H. Ashley.

No. 4—Coal resources of Dayton-Pikeville area, by W. C. Phalen.

No. 5—Economic aspects of the smoke nuisance, by J. A. Switzer.
Watauga Power Company's hydro-electric development, by Francis R. Weller.
The coal fields of Tennessee, by Geo. H. Ashley.

No. 6—Bauxite Mining in Tennessee, by Geo. H. Ashley.
A New Manganese Deposit in Tennessee, by Wilbur A. Nelson.
Road Improvement in Tennessee, by Geo. H. Ashley.

Vol. II. No. 1—The Utilization of the Navigable Rivers of Tennessee, by Geo. H. Ashley.
Dust Explosions in Mines, by Geo. H. Ashley.
The Rejuvenation of Wornout Soil Without Artificial Fertilizers, by Geo. H. Ashley.
Tennessee to Have Another Great Water Power, by George Byrne.
Manufacture of Sulphuric Acid in Tennessee in 1911, by W. A. Nelson.

No. 2—The Ocoee River Power Development, by J. A. Switzer.
Exporation for Natural Gas and Oil at Memphis, Tenn., by M. J. Munn.

No. 3—The Power Development at Hale's Bar, by J. A. Switzer.
Notes on Lead in Tennessee, by Wilbur A. Nelson.

No. 4—The Tennessee Academy of Science.
The Preliminary Consideration of Water Power Projects, by J. A. Switzer.
Lignite and Lignitic Clay in West Tennessee, by Wilbur A. Nelson.

Unimpaired railroad service over river. There was no delay of traffic at any time.

Steamboats loading at Broad Street, showing water still several feet below street level.

HIGH WATER ON THE CUMBERLAND RIVER AT NASHVILLE, APRIL 3, 1912.

BULLETIN 2-A

2—A

STATE OF TENNESSEE—STATE GEOLOGICAL SURVEY

GEORGE H. ASHLEY, State Geologist

# OUTLINE INTRODUCTION

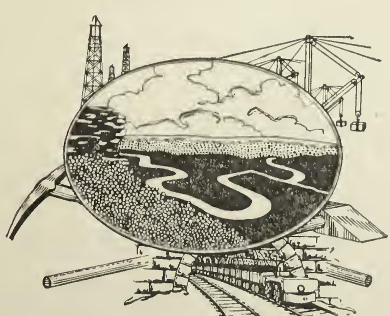
TO THE

# MINERAL RESOURCES OF TENNESSEE

Compiled and Written

BY GEORGE H. ASHLEY

EXTRACT (A) FROM BULLETIN NO. 2, "PRELIMINARY PAPERS ON THE MINERAL RESOURCES OF TENNESSEE."



NASHVILLE

FOLK-KEELIN PRINTING COMPANY

1910

## STATE GEOLOGICAL COMMISSION

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MALCOLM R. PATTERSON, *Chairman,*
*Governor of Tennessee.*

JOHN THOMPSON,
*State Commissioner of Agriculture.*

R. A. SHIFLETT,
*Chief Mine Inspector.*

BROWN AYRES,
*President, University of Tennessee.*

J. H. KIRKLAND,
*Chancellor of Vanderbilt University.*

WM. B. HALL,
*Vice-Chancellor, University of the South.*

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GEORGE H. ASHLEY,
*State Geologist.*

# CONTENTS

CONTENTS—Continued.

CONTENTS—Continued.

# OUTLINE INTRODUCTION

—TO THE—

# MINERAL RESOURCES OF TENNESSEE

By George H. Ashley.

Note.—This pamphlet will ultimately form Part "A" of Bulletin No. 2—"Preliminary Papers on the Mineral Resources of Tennessee," in which it will be followed by brief, though more extended papers, on the more important resources of the State. The several parts of Bulletin No. 2 are published separately as "Circulars of Information," as listed on the inside cover.

Bulletin No. 2 is not intended as an original contribution to the knowledge of the State's mineral resources. It contains a succinct statement of such general facts about the State's mineral resources as have been *published,* supplemented by such additional facts as may have come to the notice of the survey in the few weeks since its establishment. It is issued to meet the urgent demand for "immediate information" on the State's mineral resources, pending the appearance of reports to be prepared as a result of the Survey's field work now in progress, or to be carried on in the future.

Part A of Bulletin No. 2 is for the reader who has only a general interest in the State's resources, and to meet immediate demands, as it is recognized that it is going to require many months to prepare all the following papers, brief as they are intended to be.

Part A contains:

I. Location, Size, etc., of Tennessee.
II. Surface Features of Tennessee.
III. The Rock Formations of Tennessee.
IV. The Geological History of Tennessee in Outline.
V. The Rock Structure of Tennessee.
VI. Alphabetical List of the Minerals of Tennessee, with a Brief Notice of Their Occurrence, etc.

No attempt is made in this paper to give the authority upon which statements are made. It is hardly necessary to say that reports of Safford and Killebrew and the U. S. Geological Survey folios and "Mineral Resources" have been largely drawn upon. In most cases there has been attempted a review of all the papers dealing with the several subjects. The fuller papers on the mineral resources, which will appear in later numbers of Bulletin No. 2, will in most cases give lists of the principal papers that have been published on each subject. The statistics of production in the State and the lists of producing mines, etc., are fully set forth in the annual reports of the State Mine Inspector, and need not be repeated here. Those reports can be obtained by addressing the State Mine Inspector, Nashville, Tenn.

## LOCATION, SIZE, ETC., OF TENNESSEE.

Tennessee lies between latitude 35° 00' and 36° 30' north, and longitude 81°, 56' and 90° 28' west, with an extreme reach from east to west of 483 miles. It has a width along the parallel of 36°, 30' of 432 miles; its width along the parallel of 35° north is 336 miles; its greatest width from north to south is 115 miles, with an average of 109 miles. It has an area of 42,050 square miles, of which 300 are covered by water. It contains 96 counties, grouped into three principal divisions—East, Middle and West Tennessee—which are recognized in the Constitution in the election of judges and otherwise. In 1900 the population of the State was 2,200,616, of which 31 per cent. was colored. At this writing the census figures for 1910 are not available.

The State has four large, thriving cities—Memphis, Nashville (the capital), Chattanooga and Knoxville—and scores of smaller cities. Memphis claims to be the largest inland cotton market in the United States, if not in the world; Nashville, the largest hardwood market in the world, the largest publishing city in the United States outside of New York City, the largest educational center in the South, with 11,000 visiting students, etc.

There are at this time almost 4,000 miles of railroad track in the State. The Cumberland River is navigable for 518 miles, of which 315 are in Tennessee, the Tennessee River furnishes 320 miles of navigable river; the Mississippi 200 miles. Altogether there are about 1,200 miles of navigable streams in the State, thus insuring low freight rates to a large number of points.

Tennessee combines a southern position, with high average alti-

tude, rendering the climate one of the most equable and delightful of any State in the Union—the winters are short and the summers long, but neither the winter cold, nor the summer heat is as great as in the Northern States. The average rainfall is about 52 inches, well distributed all through the year, with an average of 265 clear days in a year. The growing season, as measured by the number of days between frosts, is 189.

With her abundant and varied mineral resources, soils and climate, Tennessee, if cut off from communication with all other States, could continue to supply herself with all, or nearly all, of the needful materials to maintain her present or future civilization. Water-power and coal would supply her with power; her iron, lead, zinc, copper, gold, silver, aluminum and other mines would supply her with metals; her building stones, marbles, clays, cement materials and forests would supply her with building materials; most of the materials used in chemistry and the arts, she could secure from her own storehouse, if cut off from outside supplies; and with the exception of tropical fruits, she can raise any food raised anywhere in the United States.

## Surface Features of Tennessee.

Though Tennessee lacks the attractive features of the seacoast and the rugged wildness of the mountains of some of the Western States, it is safe to say that no State in the Union excels it in general attractiveness of physiographic aspect. The eastern edge reaches the eastern crest of the continent, with an average elevation of 5,000 feet above sea-level, and the western edge borders on the Mississippi River, with an average elevation of about 225 feet above tide. Two great navigable rivers cross the State, one of them twice. There is a minimum of level ground, with the usual monotony of scenery, yet on the other hand the area of wild mountain lands of low economic value is very limited. To the east the great wilderness of the Appalachian mountains belong to North Carolina, and Tennessee has only the crest and the western slope, giving an abundance of mountain scenery, peaks and passes, river gorges and waterfalls, without its absorbing much of its territory. On the west the great swampy bottoms of the Mississippi lie almost entirely on the Arkansas side, while on the Tennessee side are some of the richest agricultural lands in the State, up on the bluff, where they are well drained.

The Alleghany Mountains, which in Kentucky render all of the eastern part of the State rough and rugged and of little value for agriculture, in Tennessee narrow down to the flat-topped Cumberland Plateau, and even the heart of that is occupied by the broad, fertile Sequatchie Valley.

Again, the great Central Basin of Tennessee, which is almost a continuous garden, is not flat, as are some of the States farther north, but gently rolling, rising into picturesque hills, or sinking into sloping valleys, through which run clear, rapid streams, and almost always the hills of the Highland Rim form a distant background resembling small mountains.

The State crosses a series of distinct physiographic types of topography which extend northeast and southwest in the eastern part of the State, and north and south in the western part of the State. These, from east to west, are the Unakas, or Great Smoky Mountain belt, the Valley of East Tennessee, the Cumberland Plateau, the eastern Highland Rim, the Central Basin, the western Highland Rim, the Western Valley of Tennessee River, the Plateau of West Tennessee, extending to the Mississippi River bottoms.

*The Unakas.*—This is the western flank and foothill region of the Unakas, or Great Smoky Mountains, an area of 2,000 square miles, with often rounded crests, suited for grazing, steep, timber-covered slopes and deep, gorge-like ravines opening out into enclosed valleys, a region of fine timber, great water-power and abundant grazing grounds. The crests of the mountains have an elevation of from 4,000 to 6,650 feet; the elevation at the foot of the mountains is about 1,000 feet. This region is the source of the copper, gold, silver, slate and granite of the State, and of great deposits of iron.

*The Valley of East Tennessee.*—This region has an average width of about 50 miles and an area of 9,200 square miles, with an elevation of about 1,000 feet above the sea. It is a region of long northeast-southwest limestone and shale valleys separated by narrow, saw-toothed ridges of sandstone or chert. The valleys, and often much of the slopes of the ridges, are at once beautiful, populous and fertile. The Great Valley is the seat of the State's marble industry and the source of barytes, zinc, red fossil iron ore, and many other economic products.

*The Cumberland Plateau.*—This is the coal region. It is a high table-land, capped with massive sandstones and underlain

with coals, clays, shales and limestones. The elevation is about 2,000 feet above tide, with some mountains rising above the tableland to 3,000 or 4,000 feet above tide at the northeast. It has an area of over 5,000 square miles. It faces the Great Valley with a fairly even escarpment 1,000 feet high and generally precipitous. On the western side it forms a series of projecting headlands, enclosing rich coves. From either edge of the plateau wonderful views are to be had of the broad, rich valleys to the east and west.

*The Highland Rim.*—This is a high, broad shelf surrounding the "Central Basin." The edge facing the Basin has a cherty soil, back of which is a broad belt of rich limestone country. The inner rim supplies chert, and on the western side of the Basin the "blue" phosphate rock just underlies the chert. From the outer edge of the Rim will be supplied lithographic stone and building stone, fluorite, zinc and other metals. This division has an area of 9,300 square miles, with an elevation of 950 feet above sea-level.

*The Central Basin.*—The Central Basin with an area of 5,400 square miles lies about 400 feet below the Rim, or about 500 feet above tide. It is a limestone basin. Much of the limestone of the western side is rich in phosphate, and large quantities of commercial fertilizer are now being mined. It is not flat, but beautifully rolling, the hills rising 50 to 150 feet above the adjoining broad valleys. For the most part, hill and valley are equally rich. It is one of the few regions of the world combining great agricultural richness with beautiful scenery, clear, flowing streams and health conditions of the highest type, a region of wealth, culture and influence.

*The Western Valley of the Tennessee River.*—This is a narrow, irregular belt of low, swampy land, sparsely settled, with an area of 1,200 square miles. It is a region of great possibilities for the future when the river shall have been harnessed. Some of the side valley bottoms with their great richness are prophetic of what some day may be true of the whole valley.

*The Plateau and Slope of West Tennessee.*—This is a region of rolling upland, with light, fertile soil, sluggish streams with swampy bottoms, the uplands rising 200 to 400 feet above the stream bottoms. The reclamation of the stream bottoms has already begun. The region is well supplied with railroads. It is the most densely populated part of the State and is growing rich

raising small fruits and vegetables for the early Northern market. As the stream bottoms are brought under cultivation this region will become one of the garden spots of the United States. The district gives promise of a great future industry in the manufacture of clay products. The area is about 8,850 square miles and the elevation 500 feet above tide.

*The Mississippi River Bottoms.*—Nearly 1,000 square miles of Mississippi River bottom exists in Tennessee, mostly awaiting reclamation to become what such river valleys all over the world become when properly reclaimed—the world's granaries. At present most of this area is covered with a dense vegetation, spotted with lakes and marshes, and underlain with a soil of imperishable fertility.

## ROCK FORMATIONS OF TENNESSEE.

As is well known, the rocks of any region vary—some are sandstones, some shales, some limestones, granites, marls, etc. Originally most of these rocks were laid down in the ocean, either along the shore or farther out as great stretches of sand or mud, as vast coral reefs, as gravels, or as other material, or as mixtures of these. Later these beds were buried by other materials as the constant movement of the land carried the sea farther in, or forced it farther out, and in time each bed of similar material became deeply buried beneath later materials and it was hardened into shale or sandstone, or limestone, or some other rock. But the same conditions of shore or sea often recurred at any one point, so that the same kind of bed was laid down at many times in the history of one locality. Therefore, in referring to any single bed it is desirable that it have a name. It has become customary to give each bed a name from some place where it is especially prominent, and not likely to be confused with any other similar bed at that place. Thus, the Camden chert is named from Camden, in Benton County, where it is practically the only rock to be seen. The Murfreesboro limestone is named from Murfreesboro in the same way.

These layers of rock may have a thickness of from a few feet to several thousand feet, and an extent of from a few square miles to 100,000 square miles, or more. Thus, the Knox dolomite has a thickness of 4,000 feet, and probably underlies nearly all

of Tennessee, though exposed only in East Tennessee and in the Wells Creek basin. It is found also all through the Appalachian Valley through Virginia, Maryland and Pennsylvania. The red Clinton iron ore can be traced from Lake Ontario to south of Birmingham in Alabama, and from East Tennessee to west of Nashville. It is not continuous, nor always in a single bed. When the layers of rock are thin and variable a number of them are grouped together and called a formation; as the Rome formation, or the Mingo formation, which contains shales, sandstones, clays and coal beds. The general term "formation" has been given to all of the named strata, or "formation" groups.

These formations are traced and mapped in two ways—by actual tracing from place to place, and through the study of the contained fossils. In the Western States where rain is scarce and vegetation scanty the rocks are commonly well exposed, and it is often possible to trace a given rock layer for hundreds of miles, but in Eastern United States where the vegetation is usually abundant this is seldom possible, and always difficult. Again, the dips, faults, or other structural features often carry the stratum being traced underground for a long distance, or have raised it above the present surface, so that it has been eroded, and under these conditions the direct tracing may not be possible. In almost all cases, therefore, where the tracing is carried any distance dependence must be placed on a study of the fossils.

The fossils are the remains of the animals and plants that lived at the time any rock was being laid down. A study of the rocks shows that there has been a steady change and advance in the plants and animals living in the sea at the time the various rocks were laid down. Hundreds of thousands of different forms have been recognized and described. Where two layers follow each other closely in time it is found there is a close resemblance between the animals or plants, but invariably it is found that some forms in the lower layer are lacking in the upper layer, and new forms have appeared in the upper layer, generally descended from the missing forms of the lower layer. In ascending through several layers it is soon found that all of the forms have changed. Again, in closely succeeding layers, it is often found that where the same species has persisted from one layer to the next that it shows some slight variation by which it is possible to recognize what particular bed a given specimen was taken from. To recognize these minute variations, however, requires an amount of

study, training and experience that shuts out all but those who are willing to devote their whole time to it, and as a rule most of the paleontologists confine themselves to either the plants or animals of a single era. Notwithstanding this necessary specialization for the detailed work, the general geologists, or laymen, can quickly learn the common fossils of the larger rock groups, so as to readily distinguish them.

The practical value of the study and knowledge of the rock formations lies in the fact that a large part of the economic products of any region have certain definite relations to the rock formations. Thus, the bituminous coal of Tennessee is found only in rocks of Carboniferous age and the lignite in certain other rocks of Eocene age, the blue phosphate in close association with the Chattanooga black shale, or brown phosphates on the edges of the Trenton and Lorraine limestones or fossiliferous red iron ore in rocks of Clinton age; the bauxite of Tennessee is found associated with the Knox dolomite, as is most of the zinc ore. The Holston marble is found in a definite stratigraphic position, as are the lithographic limestones and the oölitic (Bedford) building limestones. The same is true also of the oil, gas, novaculite, chert, slate, cement rocks, and many other of the State's resources. If we wish to find deposits of any materials, a knowledge of the rock strata and where they occur serves as a guide in the search; or in finding a given formation we look for the possible occurrence of certain economic deposits.

Following are given first a list of the named formations of the State, arranged to show the correspondence in age; then a brief characterization of each, giving its thickness, the location of its outcrops, etc.

## TABLE OF ROCK FORMATIONS IN TENNESSEE

F-Formation; S.S.-Sandstone; L.S.-Limestone; Sh.-Shale; Cgl.-Conglomerate; Sl.-Slate; Qtz.-Quarzite; Gr.-Group; Sd.-Sand; Cl.-Clay; Ch.-Chert.

| | Standard | Section | Safford, 1869 | Western Tennessee | Eastern Tennessee |
|---|---|---|---|---|---|
| Era. | System | Series and Groups | | | |
| Cenozoic | Quaternary | Recent | Alluvium<br>Eastern Gravel | Alluvium | Alluvium<br>High level gravel |
| | | Pleistocene | Bluff Gravel | Columbia: Milan loam<br>Memphis loess<br>sand | |
| | Tertiary | Pliocene<br>Miocene<br>Oligocene | | Land | Land |
| | | Eocene | Bluff lignite<br>Orange sd. or Lagrange | Lagrange F. | Land |
| | | | Porter's Creek F. | Porter's Creek F. | Land |
| Mesozoic | Cretaceous | Upper | Ripley group | Ripley F. | Land |
| | | | Green sd. | Selma Cl. | |
| | | | Coffee sd. | Eutaw Sd. | |
| | | Lower | Land | | |
| | Jurassic | Upper<br>Middle<br>Lower | Land | Land | Land |
| | Triassic | Upper<br>Middle<br>Lower | Land | Land | Land |

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| Era | System | | Series and Groups | Safford 1869 | Safford and Killebrew 1900 | Cumberland Gap Ashley & Glenn 1904 | Northern Appalachian Field Keith | Southern Appalachian Field Hayes |
|---|---|---|---|---|---|---|---|---|
| Paleozoic | Carboniferous | | Permian | | | | | |
| | | Pennsylvanian | Monongehela | | | probably | land | |
| | | | Conemaugh | | | | | |
| | | | Allegheny | | | probably | eroded | |
| | | | Pottsville | Upper Coal Measures | Brushy Mt. Gr. | Bryson F.<br>Hignite F.<br>Catron F.<br>Mingo F.<br>Hance F. | And'rs'n S.S<br>Scott Sh.<br>Wartb'g S.S.<br>Briceville Sh | Eroded |
| | | | | The Conglomerate. | Emery S.S.<br>Tracy City Gr<br>Sewanee S.S.<br>Bon Air Gr. | Lee F.: Naesa S.S. Member | Lee F.: Rock-castle Cgl.<br>Bon Air Cgl. | Walden S.S.<br>Lookout S.S. |
| | | Mississippian | Chester | Mountain L.S | Mountain L.S. | Pennington Sh | Pen'gton Sh. | Bangor L.S. |
| | | | St. Louis | Siliceous Gr.: St. Louis | St. Louis L.S. | Newman L.S. | Newman L.S | |
| | | | Keokuk | Siliceous Gr.: Lower or Protean Gr. | Tullahoma | | | |
| | | | Burlington | | | | | |
| | | | Kinderhook | | | | Waverly F. | Fort Payne Ch |

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Qtz.-Quartzite; Gr.-Group; Sd.-Sand; Cl.-Clay; Ch.-Chert.

| Era | System | Series and Groups | | Safford 1869 | S. & K. 1900 | Western half of Tennessee | | Eastern half of Tennessee |
|---|---|---|---|---|---|---|---|---|
| Paleozoic | Devonian | | | | Maury Green Sh. | | Maury Sh. | Grainger Sh. |
| | | | | | Black Sh. | | Chattanooga Sh. | Chatta. Sh. |
| | | Upper | Chemung | Blackshale | Hardin S.S. | | Hardin S.S. | |
| | | | Portage | | Swan Creek Phosphate | | Swan Cr. Phosphate | |
| | | Middle | Hamilton | | | | | |
| | | | Onondaga | | | | Onondaga L.S. | Land |
| | | Lower | Oriskany | | Camden Ch. | | Camden Ch. | |
| | | | Helderb'g | Lower Helderberg | Linden L.S. | | Linden L.S. | |
| | Silurian | Cayuga | Monroe | | | | Land | |
| | | | Salina | | | | | |
| | | Niagara | Guelp | Menison's Limestone: Sponge Bearing Bed | | Clifton Limestone | Decatur L.S. | |
| | | | | | | Clifton Limestone: Brownsport | Lobelville F. | Sneedville L.S. |
| | | | | | | | Bob F. | |
| | | | | | | | Beech Riv. F. | |
| | | | Lockport | Menison's Limestone: Variegated Bed | Clifton L.S. | Clifton Limestone | Dixon F. | Hancock L.S. |
| | | | | | | Clifton Limestone: Glenhook | Lego L.S. | |
| | | | | | | | Waldron Sh. | |
| | | | | | | | Laurel S.S. | |
| | | | Rochester | | | Clifton Limestone: Maddox | Osgood | |
| | | Clinton | | Dystone Gr. White Mt. S,S. | Dystone Gr. | Maddox | Clinton F. | Rockwood F. |
| | | Medina | | Clinch Mt. S.S. | Clinch Mt. S.S. | | Land | Clinch S.S. |
| | | | | | | | | Bays F. |

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| Era | System | Series and Groups | | Safford 1869 | | S. & K. 1900 | | West half of Tennessee | East half of Tennessee | |
|---|---|---|---|---|---|---|---|---|---|---|
| Paleozoic | Ordovicin or Lower Siluran | Cincinnati | Richmond | Nashville | Upper | Nashville | Hudson or College Hill | Mannie Sh. Ferndale F. Arnheim (Warren) F. | Sevier Shale | Sevier Sh. |
| | | | Maysville | | | | | | | |
| | | | Lorraine | | | | | Land | | |
| | | | Eden | | | | | Leipers F. | | Tellico S.S. |
| | | | Frankfort | | | | | Land | | |
| | | Mohawk | Utica | | | | Criptodonta & Stomatopora bed | Land Catheys L.S. | | |
| | | | Trenton | | Middle | | Dove & Ward L.S. Capital or Mt. Pleasant L.S. | Bigby L.S. | | Athens Sh. |
| | | | | | orthis bed | | orthis bed | Hermitage L.S. Saltillo L.S. | | |
| | | | Black Rvr. | | | | | Land | | |
| | | | Lowville | | | | | | Moccasin L.S. | |
| | | Chazy | Upper | Trenton or Lebanon | Center | Stone's River | Center lst. | Carter L.S. | Holston marble | |
| | | | | | Glade | | Lebanon lst. | Lebanon L.S. | | |
| | | | | | Ridley | | Ridley lst. | Ridley L.S. | Chickamauga L.S. | |
| | | | Stones River | | Pierce | | Pierce lst. | Pierce L.S. | | |
| | | | | | Central | | Murfreesboro lst. | Murfreesboro L.S. | Lenoir L.S. | |
| | | | | | | | | | Knox Dolomite upper 2,000 | |

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| Era | System | Series and Groups | Safford 1869 | Valley of East Tennessee | | | Cranberry Folio (a) or Nantahale Folio (b) | Ocoee of Knoxville Folio |
|---|---|---|---|---|---|---|---|---|
| | | | Knox Dol'mite | Knox Dolomite | | | | |
| Paleozoic | Cambrian | Saratoga | Knox Shale | Connasauga Sh | | Nolichucky Sh. | | |
| | | | | | Honaker lst. | Maryville L.S<br>Rogersville<br>Rutledge L.S | | |
| | | | Knox Sandstone | Watauga sh. | | Rome form (Russel)<br>Beaver L.S.<br>Apison sh. | | |
| | | Arcadian | Chilhowee Sandstone and Ococe | Shady L.S.<br>Hesse Qtz.<br>Murray Sl.<br>Nebo Qtz.<br>Nichols Sh. | | | (a) Erwin Qtz.<br>(a) Hampton Sh.<br>(a) Unicoi F.<br>(b) Tusquito Qtz.<br>(b) Natahala Sh. | |
| | | | | Cochran cgl. | | | (b) Great Smoky Clz | Clingman Cgl.<br>Herzel Sl.<br>Thunderbreed Clz. |
| | | Georgia | | Hiwassee Slate | | | | Cades Cgl.<br>Pigeon Sl. |
| | | | | Snowbird F. | | | (a) Starrs Cgl. lent.<br>(b) Sandsuck Sl. | Citico Cgl.<br>Wilhite Sl. |
| Algonkian | | | | | | | (b) Metarhyolite<br>(b) Lynnville metadiabase | |
| Archean | | | | | | | Beech granite<br>Max Patch granite<br>Cranberry granite | |

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## CENEZOIC ERA, QUARTENARY SYSTEM, RECENT SERIES.

*Alluvium.*—Recent deposits along river and stream bottoms; all over the State, especially in West Tennessee. Rich agriculturial lands; source of brick clays and locally of sand and gravel.

*High-level gravels.*—Gravel, reaches often 300 to 400 feet above streams in East Tennessee, and especially in the gaps of the Unakas. Gravels up to the size of a man's head and extending back from streams as much as three or four miles.

## PLEISTOCENE (COLUMBIA).

*Milan loam.*—Yellow clay loam without laminar structure, containing fine sand; 0 to 15 feet thick, average 3 feet. Fine agricultural land. Plateau of West Tennessee.

*Memphis loess.*—Fine, siliceous,, calcareous earth, ashen to buff color, up to 100 feet thick. Vertical walls in cuttings stand for years. Uplands along the Mississippi River.

*Sands (Lafayette).*—Soft, loose, light-colored sand, with rounded pebbles; four to five feet thick, and up to 10 or 12 feet. West Tennessee.

## MESOZOIC ERA, TERTIARY SYSTEM, EOCENE SERIES.

*LaGrange formation.*—Orange, red, yellow and white sands, and beds of gravel, often locally compacted or cemented, with lenses of plastic, siliceous clay. 200 feet thick. Yields clay for tile and brick; lignite; iron ore. West Tennessee.

*Porter Creek formation.*—Fine grained clay, gray when dry, or dark to black when wet, with some interbedded sands, or sandstones; some green sands and impure limestone. 200 to 300 feet thick, narrow outcrop across West Tennessee, west of Tennessee River.

## CRETACEOUS SYSTEM (UPPER).

*Ripley formation.*—Colored sands and clays, 400 to 500 feet thick, containing some lignite. Some pottery clay. Makes belt 6 to 12 miles wide, west of Tennessee River, east of Porter Creek formation.

*Selma clay.*—Gray to green clay, with glauconite, fossil shells

yielding lime; 100 to 375 feet thick. Outcrops only in the southeast part of West Tennessee.

*Eutaw sand.*—Variable sand, with some clay; 250 feet thick, southeast corner of West Tennessee.

## PALEOZOIC ERA; CARBONIFEROUS SYSTEM; PENNSYLVANA SERIES. POTTSVILLE GROUP.

(Upper Pottsville, or "Brushy Mountain Coal Group.")

The first five formation names given below were used in the Cumberland Gap area for the upper Pottsville rocks. The next four were used for the same general group of rocks in the Briceville and Wartburg folios. These formations are confined to the northeast part of the Cumberland Plateau.

*Bryson formation.*—Sandstones interbedded with shales, coals and clays; 200 feet thick in Bryson Mountain.

*Hignite formation.*—Shales interbedded with sandstones, coals and clays; 440 to 550 feet thick. Several thick coal beds.

*Catron Formation.*—Shales and sandstones, interbedded with coals and clays. Numerous workable coal beds; 280 to 360 feet thick.

*Mingo formation.*—Shales and sandstones, interbedded with coals and clays; many workable beds. 950 feet.

*Hance formation.*—Mostly shale, with some interbedded sandstones, coals and clays; 600 feet thick. Several workable beds.

*Anderson sandstone.*—Sandstone interbedded with shale and coal beds; 1,000 feet thick.

*Scott shale.*—Shale, with some sandstones; thin coals; 500 to 600 feet thick.

Wartburg sandstone.—Interbedded sandstones, shales and coal beds; 500 to 600 feet thick.

*Briceville shale.*—Shale with thin sandstone and thick coal beds; 250 to 650 feet thick.

## LOWER POTTSVILLE, OR LEE CONGLOMERATE.

*Emory sandstone.*—Massive sandstone, usually conglomeratic; 100 to 150 feet thick; under all of the east part of the Plateau region.

*"Tracy City group."*—Mostly sandstone, with interbedded shale, coals and clays; 500 to 600 feet thick.

*Bon Air conglomerate, or Sewanee conglomerate.*—Massive

sandstone 40 to 100 feet in thickness, usually conglomeratic, forming the top of Lookout formation. Used in the Pikeville, Chattanooga, Kingston, Sewanee and McMinnville folios. Used as a building stone.

*"Bon Air Group."*—Mostly sandstone, with some shale, coals and clays; 0 to 600 feet thick.

## MISSISSIPPIAN SERIES.

*Pennington shale.*—Calcareous shale, sandstone and thin limestones, showing often bright red in color; 160 to 1,000 feet thick along east and west escarpments of Plateau.

*St. Louis limestone.*—Gray and blue thin-bedded limestone, with chert nodules; 250 to 300 feet thick; outcrops around Highland Rim, back from the edge. Yields lithographic and oölitic limestone. Good agricultural land.

*Tullahoma limestone.*—In Middle Tennessee, mostly chert, with some limestone and siliceous shale; 200 feet to 1,200 feet thick. Makes inner edge of Highland Rim around Central Basin in Middle Tennessee, and makes chert ridges in East Tennessee.

*Newman limestone.*—Includes last two formations in northwest part of Valley of East Tennessee; 650 to 750 feet thick.

*Waverly formation.*—Used in the Standing Stone folio for the bottom 400 to 500 feet of the Carboniferous.

*Bangor limestone.*—Blue crinoidal limestone, with few lenses of sandstone and chert near the bottom. Includes the Pennington, St. Louis and upper part of the Tullahoma. In folios in southern part of East Tennessee. Thickness 800 to 850 feet.

*Ft. Payne chert.*—Chert, in the main; used in the southern part of East Tennessee for the lowest 150 to 200 feet of the Tullahoma.

## DEVONIAN SYSTEM.

(In a recent paper Schuchert assigns the Chattanooga black shale to the Lower Carboniferous. Corelations used in the Columbia folio have been followed here.)

*Maury shale.*—Green, or greenish shale; a few inches to 4 or 5 feet thick, generally containg concretions of all sizes and shapes, with calcium phosphate; especially western Middle Tennessee.

*Chattanooga shale.*—Black bituminous shale; 0 to 450 feet thick; usually only a few feet in thickness, but very persistent,

and found in all divisions of the State. Probably the source of much of the oil and gas of the State, sulphur waters, etc.

*Hardin sandstone* (*Swan Creek phosphate*).—A dark, fine-grained, bituminous sandstone in Hardin, Wayne and Perry counties; 12 to 15 feet thick. Becomes phosphatic farther north, locally losing all, or nearly all of its sand grains—the blue phosphate rock of commerce. Where phosphatic usually less than 4 feet thick. Northwest part of Middle Tennessee.

*Camden chert.*—Light to white chert, or novaculite; 60 feet thick. Benton and adjoining counties, and Wells Creek Basin. Novaculite very fossiliferous. Fine road material.

*Linden limestone.*—Blue thin-bedded limestone and interbedded shale. Very fossiliferous; 100 feet and less thick. North part of Western Valley of Tennessee.

## SILURIAN SYSTEM.

*Note.*—The following formations down to Osgood have been differentiated only in part of the western valley of the Tennessee, notably in Decatur and Perry counties:

*Decatur limestone.*—Massive white, coarsely cyrstalline, crinoidal, magnesian, limestone; 70 feet thick. Found in Decatur county.

*Lobelville formation.*—In two zones; coral zone, 45 feet thick, yellow clays and thin argillaceous limestone, full of corals. Bryozoan zone, 31 feet thick. White to blue shale, or red to purple shale, or shaly limestone.

*Bob formation.*—Occurs in three zones. Conchidium zone, 15 feet thick; massive crinoidal, and argillaceous, limestone. Dictyonella zone, 30 feet thick; blue clay and shale. Uncinulus zone, 30 feet thick, gray massive limestone.

*Beech River formation.*—Blue to white shale, with limestone; 106 feet thick.

*Dixon formation.*—Red to purple shale, and shaly limestone; 44 feet thick.

*Lego limestone.*—Compact gray to white clay, or gray to white argillaceous to sub-crystalline limestone; 46 feet thick.

*Waldron shale.*—White indurated clay and argillaceous limestone; 4 feet thick.

*Laurel limestone.*—Massive pink, or reddish purple, clay and argillaceous limestone; 28 feet thick.

*Osgood limestone.*—Thin-bedded, reddish, argillaceous limestone; 14 feet thick.

*Clifton limestone.*—General name for the above formations of Niagara age, where undivided when traced farther east and north; 200 feet thick. Source of much building stone. In northwest part of Middle Tennessee.

*Hancock limestone.*—Massive blue limestone and bluish gray shaly limestone, 400 to 450 feet thick; in the north part of the Valley of East Tennessee.

*Clinton formation; Rockwood formation.*—Variegated, calcareous shales with thin fossiliferous limestone and thin, smooth sandstones; 100 to 300 feet thick. Contains valuable red Clinton iron ore, with a thickness of from a few inches to 8 feet; in ridges of East Tennessee and along the east foot of Cumberland Plateau, and in small thickness in Middle Tennessee.

*Clinch sandstone.*—Hard, gray sandstone in crests of mountains in East Tennessee; 200 to 500 feet thick.

*Bays formation.*—Red calcareous and argillaceous sandstone and limestone; 200 to 500 feet thick. East Tennessee.

## ORDOVICIAN, OR LOWER SILURIAN SYSTEM.

*Sevier shale.*—Light blue sandy and calcareous shale, with beds of shaly limestone and argillaceous marble 1,000 to 1,500 feet thick. In East Tennessee.

*Mannie shale.*—Brown and blue shaly clay, in the western valley of Tennessee; 0 to 25 feet thick.

*Ferndale formation.*—Blue shale in upper half; coarse-grained, cross-bedded, light-colored phosphatic limestone, in lower half; 0 to 35 feet thick; in embayments in western Middle Tennessee.

*Arnheim (Warren) formation.*—Coarsely crystalline, phosphatic limestone, with abundant chert. Three feet thick. Western valley of Tennessee.

*Tellico sandstone.*—Bluish gray and gray calcareous sandstone and shale, 800 to 900 feet thick; in knobs of East Tennessee.

*Leipers formation.*—Knotty, earthy limestone to uniform granular limestone, the whole highly phosphatic; 0 to 100 feet thick.

*Athens shale.*—Light blue calcareous shale to black carbonaceous shale; 1,000 feet thick.

*Catheys formation.*—Fine-grained blue, earthy limestone at

the top, shales and limestone in the middle, heavy-bedded subcrystalline limestones at the bottom, sometimes including phosphatic layers; 0 to 1,000 feet thick.

*Bigby limestone.*—Uniform, granular limestone, or laminated limestone, with thin beds of shale; 30 to 100 feet thick. Main source of "brown" phosphate.

*Hermitage (Saltillo) limestone.*—Even-bedded limestone alternating with thin layers of argillaceous, siliceous limestone, shale and siliceous, granular limestone; more or less phosphatic in upper part. Thickness, 40 to 70 feet.

The last three formations are recognized only in the western part of Middle Tennessee.

*Moccasin limestone.*—Red and gray, flaggy limestone and calcareous shale; 300 to 500 feet thick. Northern part of East Tennessee.

The following occur in rings about the Murfreesboro limestone, which has a circular outcrop at Murfreesboro:

*Carters limestone.*—Heavy bedded, fine grained, white to light blue limestone, with chert; 40 to 50 feet thick.

*Lebanon limestone.*—Thin-bedded, often shaly, fine grained, blue or dove colored limestone; thickness, 70 to 100 feet.

*Ridley limestone.*—Thick-bedded, light blue limestone; 95 feet thick.

*Pierce limestone.*—Thin-bedded, bluish, fossiliferous limestone; 27 feet thick.

*Murfreesboro limestone.*—Light blue, heavy-bedded limestone, often cherty; 70 feet thick.

All of the following formations are found only in East Tennessee, except small outcrops in the Wells Creek Basin, reaching down to the Knox dolomite:

*Chickamauga limestone.*—Blue and gray limestone, sometimes massive, sometimes shaly, and containing the Holston marble, and the Lenoir limestone at its base. Thickness 0 to 2,400 feet.

*Holston marble.*—Layers occurring in the Chickamauga limestone. Variegated marble, brown, red, gray and white. Thickness 0 to 300 feet.

*Lenoir limestone.*—A stratum of blue, shaly limestone at the base of the Chickamauga. Thickness 50 to 600 feet. Probable source of cement limestone.

*Knox dolomite.*—Only the upper part of the Knox dolomite is of Ordovician age, however, will be all described here: magnesian

limestone, light and dark blue and white, with nodules of chert. A few thin standstone beds. Thickness 3,000 to 4,400 feet.

## CAMBRIAN SYSTEM.

The Knox dolomite forms the upper part of this system in Tennessee.

*Nolachucky shale.*—Yellow, red and brown calcareous shale, with a few limestone beds; 400 to 750 feet thickness.

*Maryville limestone.*—Massive blue limestone; 500 to 750 feet thick.

*Rogersville shale.*—Bright green, clay shale, with limestone beds; 70 to 250 feet thick.

*Rutledge limestone.*—Massive blue limestone, with a few shale beds at the base; 200 to 500 feet thick.

*Connasauga shale.*—The name used for the last named four formations where not differentiated; 500 to 6,000 feet thick.

*Honaker limestone.*—The name used for the last three formations when not differentiated.

*Rome formation.*—Red, green, yellow and brown shales and sandy shales; in the lower part sandstones and shales of the same color. Also called the Russell formation; 1,600 to 2,600 feet thick.

*Beaver limestone.*—Massive, blue limestone; 300 feet thick.

*Apison shale.*—The upper 200 feet green, argillaceous shale, with 900 feet or more of bright red, green and brown, sandy shales below; 1,500 feet thick.

*Watauga shale.*—The name used for the formations, including the Rome and Apison, where not differentiated.

*Shady Limestone.*—Gray, bluish gray, mottled gray and white limestone, with masses of chert; about 1,000 feet thick.

*Hesse, or Erwin quartzite.*—Massive, white quartzite and sandstone; 700 to 800 feet thick.

*Murray slate, or Hampton shale.*—Bluish gray to gray, argillaceous, sandy shale and slate, with thin sandstone seams; 300 to 400 feet thick.

*Nebo quartzite, or sandstone, Tusquito quartzite.*—Massive, white quartzite and sandstone, coarse and fine, with a few layers of sandy shale, reddish sandstone; 20 to 900 feet thick.

*Unicoi formation.*—Massive white sandstone, feldspatic sandstone and quartzite, with interbedded shales and sandstones in the upper part. A thin bed of amygdaloid near the middle and

conglomerate arkose and graywacke in the lower part; 1,500 to 2,500 feet thick.

*Nicholas shale or Nantahala slate.*—Bluish gray to gray, argillaceous and sandy shale, with thin sandstone layers; 400 to 700 feet thick.

*Cochran conglomerate, or Great Smoky conglomerate.*—Massive quartz conglomerate and quartzite. Light and dark gray, with dark slate, altered toward the south into coarse and fine graywacke quartzite, with beds of black schist, mica and ottrelite schist; 200 to 6,000 feet thick.

*Clingman conglomerate, Hazel slate, Thunderhead conglomerate.*—(Names used for metamorphosed portions of the Cochran conglomerate as a part of the "Ocoee," when their stratigraphic position was unknown.)

*Hiwassee slate.*—Blue, gray, black and banded slate, with a fine mica schist; includes layers of sandstone conglomerate and beds of calcareous sandstone; 500 to 1,500 feet in thickness.

*Cade's conglomerate, Pigeon slate.*—Ocoee names corresponding to the Hiwassee slate, the names having been used before the correlation was determined.

*Snowbird formation.*—It contains the Starrs conglomerate lintel.

*Sandsuck shale.*—The name used for the Hiwassee and Snowbird formations where not differentiated.

*Citico conglomerate, Wilhite slate.*—White slate formations. Names of the "Ocoee," used before their correlation had been determined.

In the Nantahala folio a metarhyolite and the Lynnville metadiabase are questionably assigned to Algonkian age. Below those are the granites to which the names Beech granite, Max Patch granite, and Cranberry granite have been given.

## A BRIEF OUTLINE OF THE GEOLOGIC HISTORY OF TENNESSEE.

Our first knowledge of Tennessee comes in early Cambrian time, during which time, it has been recognized, some of the rocks of East Tennessee were laid down. That a vast extent of time existed before the Cambrian, and that during pre-Cambrian time Tennessee may have had as many interesting episodes as

since that time is well recognized, but the records of those episodes have been erased and can not be followed today. In early Cambrian, or Georgian time the whole State appears to have been a land surface, except the extreme eastern edge and the Valley of East Tennessee. There, in a long strip of water, extending northeast and southwest, shales and sandstones were being laid down. In upper Arcadian time the north part of Middle Tennessee alone was out of water, and the rest of the State was receiving deposits, still largely shale and sandstone, though some limestone deposits were laid down in the eastern counties. In late Cambrian time all of the State was under water receiving the Knox dolomite, which shows in East Tennessee, and the Wells Creek Basin of Stuart and Houston counties. In Lower Ordovician time the State was still under water, with limestones being laid down and dolomite, as in the upper Knox dolomite. Similar conditions existed through middle Ordovician time, or Stones River time, the marble of East Tennessee being laid down at this time, and the limestones which now form the surface over the center of the basin in Middle Tennessee. In Lowville time a large dome lifted most of the Central Basin out of the water, and a thin strip in East Tennessee, but the rest of the State was still receiving deposits. With the beginning of the Trenton there was a subsidence, and most of the dome was submerged, the submergence continuing until in Middle Trenton the dome was entirely submerged. Vast quantities of almost microscopic shelled animals, whose shells were composed of lime phosphate instead of lime carbonate, resulted in the phosphate deposits of Western Middle Tennessee, while in the eastern counties the deposits were mostly shale, with some limestone.

Then came a general uplift in Utica time, and no deposits were laid down in the State. This land condition continued into Lorraine time, when subsidence allowed deposits over most of Tennessee, the Leipers formation in western, and the Tellico sandstone in eastern Tennessee, were laid down. The old dome about Murfreesboro was still apparent; its center not having been submerged.

In Richmond time the land conditions extended to the southeast by emergence, with deposition in East Tennessee, and west of the basin of the Central Basin. The emergence continued into the early part of the Silurian, or until all of the State was out of water, except a narrow strip in East Tennessee where the

Clinch sandstone and Bays formation were laid down, and west of the Tennesse River. In late Clinton time there was wide submergence over all except the Central Basin, and the deposition of the red fossil iron ore in East Tennessee and west of the Central Basin. In the middle Silurian the Central Basin and Eastern Tennessee were above tide, while deposits were being laid down in West Tennessee, the area of sea gradually narrowing until at the end of the Guelph time land conditions existed all over the State. The Silurian closed with a small incursion of the Bristol district.

At the beginning of Devonian there was a general incursion of the sea from the south in West Tennessee and the Chattanooga district with a fluctuating shore-line. These fluctuations continued, sometimes the State being entirely out of water, until the Chattanooga black shale was laid down over nearly the entire State.

During Mississippian time the State was generally under water, though for short periods, as during Forest Glen, uplifts raised most of the State above sea-level.

In early Pennsylvanian time the plateau region was an area of swamps, with many fluctuations bringing in deposits of shales, sandstones, and limestones, but alternated with the swampy conditions, which resulted in coal. The land must have been low, and probably near sea-level. Middle Tennessee remained above tide, and western Tennessee was probably receiving marine deposits.

In late Pennsylvanian time this State became a land area and remained so through most of the Mesozoic, or until well into the Cretaceous. This long land period, however, followed great structural changes in East Tennessee. All through the Cambrian, Ordovician, Silurian, Devonian and Carboniferous time vast deposits of rock were being laid down in East Tennessee. Though there were many slight uplifts with land conditions, on the whole the land had been sinking, and into the great basin thus formed sediments had been accumulating until they had a depth of many miles, and corresponding quantities of rock had been removed from adjoining parts of the earth's crust. Without going into detail, the final result was the need of readjustment of weights and strains over a large area of the earth's surface (for similar conditions had existed extensively). Without concerning ourselves with what may have taken place at a considerable depth, at the surface there was a gradual apparent

giving away along the whole eastern part of the United States, the forces apparently acting from the southeast, the rocks being pushed to the northwest, folding, breaking, squeezing up into mountains, and at the east becoming crushed and metamorphosed. It should not be thought for a moment that this change took place suddenly. It is more than probable that had we been living at that time we should have had no more visible evidence of the enormous changes taking place than they have today in California and Japan, where it is evident that earth forces are engaged in some stupendous changes in the earth's surface. It should be remembered in this connection that close studies of the sea-level show that nearly everywhere on the face of the earth the land adjoining the sea is either slowly rising or sinking, and such forces as those which folded up the Appalachian Mountains are still active, and may be in active progress in many parts of the globe today. Again, it should not be supposed that because this great thickness of rocks was shoved into great folds, which if complete would extend many miles above the present surface, that mountains of such height ever existed in the eastern part of the State. Just as the mountain-making forces probably acted with great slowness over long ages, so at the same time the forces of erosion during those same ages were actively cutting down the mountains, though possibly not as fast as they were uplifted, but on the whole, during this long land period, covering most of the Mesozoic era, the surface of the rocks of this State appear to have been worn down more or less nearly to a gentle plain. The Unakas on the east edge of the State, and many of the higher mountains in the northeastern part of the plateau region, still projected above this gentle plain as hills or small mountains. Early in Cretaceous time there appears to have been seaward tilting of the land, allowing the Cretaceous sea to creep up over the land, resulting in extensive deposits along the Atlantic Coast, and in the southwest corner of the State. During Cretaceous time this movement continued, so that in Middle Cretaceous time all of West Tennessee was under water and receiving deposits. With many variations this condition continued through the Lower Tertiary or Eocene time, when again general land conditions ensued. In Pleistocene time West Tennessee appears to have been under water and deposits of sand and loam laid down. It was during this time that the northern part of the United States underwent a series of

invasions by great ice-sheets, and the water from these ice-sheets brought large deposits along the Mississippi Valley; the final retreat of the ice ushered in the present conditions, which have changed little since then.

In addition to the movements which have influenced the position and character of the deposits, have been broad movements, recorded mainly in the physiography of the State—the uplifting of the Cumberland Plateau, the erosion of the Basin of Middle Tennessee, in the many changes in the courses of the Tennessee and other rivers. Space will not permit of going into details of these movements and changes here.

## THE LAY OF THE ROCKS, OR STRUCTURE OF TENNESSEE.

In the eastern edge of the State, in the flanks and foothills of the Unakas, the rocks have been subjected to pressure, folding, and possibly heat, until they have lost all resemblance to their original condition, and appear as a great complex or mixture of granites, gneisses and metamorphosed slates, quartzites and conglomerates, of which it is hardly possible to more than map the area of surface exposure without attempting to determine the unknown extension of the rocks underground.

Coming out into the Great Valley the slates and quartzites change to shales and sandstones, and the great body of late Cambrian and post Cambrian limestones are found across the whole width of the Valley. These rocks have been closely folded in long, often straight, northeast-southwest folds, as though compressed from the southeast, just as when a bolt of cloth lying spread out on a counter is pushed from one end. The beds of rock have been pushed forward until they are found standing at high angles, or vertically, or frequently overturned. Close study has shown that often these folds have broken, and parts of the rocks have been shoved over the adjoining rocks, sometimes for miles.

The movement seems to have largely spent itself in the Valley, for on reaching the Plateau it is found that in a very short distance the rocks become horizontal and apparently unaffected by the folding. That they were affected by the titanic forces that produced the folding and yielded to them to a certain extent is shown by the existence of the sharp Sequatchie Valley fold well

within the plateau region, extending two-thirds the way across the State, and by the Pine Mountain fault and other faults at the north where the strata have been forced forward several miles overriding the strata behind them.

In general, from the eastern front of the Plateau the strata have a gentle rise to the northwest until the Cincinnati-Nashville arch or anticline is reached, when they turn and descend gradually to the west. The axis of this arch passes near Murfreesboro. This arch has been further affected by another less pronounced articline extending from the northwest to the southeast across the State, crossing the axis of the first arch near Murfreesboro and the plateau region near Chattanooga. The effect has been to produce a sort of dome where the two axes cross near Murfreesboro, the lowest formation there being exposed in an oval and the successively higher formations appearing in oval rings around it. The Central Basin owes its existence to this domed structure, and not to its having been a lake basin, as has sometimes been suggested. The affect of the northwestern axis on the coal-bearing rocks is seen in the fact that while at the north edge of the State the base of the coal measures is 1,000 feet below sea-level, at the south end of the State the same base is 1,500 feet above sea-level. Though the general dips in all of the central plateau regions are very slight, there are many local rolls in the strata, and occasionally small faults. West of the Cincinnati-Nashville anticline the rocks are nearly flat, with a slight westward dip until they disappear under the Cretaceous rocks of West Tennessee. The working out of the structure west of Murfreesboro is complicated by the fact that this arch begins to date away back in Ordovician time, at which time the axis rose above sea-level, and the succeeding formations for the most part were deposited against the irregular flank of the exposed arch.

Thus the relation of the Palezoic rocks to the overlying Mesozoic has not been worked out. Whether deposits were laid down in a basin carved out of the earliest rocks, whether they were deposited in overlapping sheets on the sinking floor of the earlier rocks, or whether the earlier rocks were first beveled and then overlapped, has not been shown. The later rocks of Cretaceous and Eocene age have a gentle dip to the westward and the Mississippi River. The Quarternary beds are most prominent in West Tennessee, lying as a mantle over the irregular surface of the earlier beds.

# ALPHABETICAL LIST OF THE MINERALS OF TENNESSEE, WITH A BRIEF NOTICE OF THEIR OCCURRENCE, USE, ETC.

*Alum.*—Alum is a white mineral, with a well-known taste. It is found in nature as a silky efflorescence or crust on the edge of the shales, especially where protected from the weather, as in rock-houses, where shales containing pyrite have weathered back under an overhanging ledge of sandstone. The alum is formed by the oxidation of the pyrite into sulphuric acid, which then combines with the alumina of the shale, and with some other element usually present in the shale, as potash, in the formation of common alum, or with iron, magnesia or soda to form other alums.

Alum occurs abundantly in the "rock-houses" of Tennessee, notably in Cannon, Coffee, DeKalb, Franklin, Giles, Jackson, Lincoln, Overton and Putnam counties. It is not known that any alum is obtained in this State on a commercial scale at present.

*Barite, or Barytes.*—Tennessee stands second among the States in the production of barytes, being exceeded only by Missouri. Barytes, often called heavy spar from its weight, is barium sulphate. It has the formula $BaSO_4$, or $BaO+SO_3$, (baryta) 65.7% sulphur trioxide 34.3%=100. It is a heavy mineral, commonly having a white color, but with a range to dark brown.

Its principal use is for the adulteration of white lead; the mixture Venice white lead contains one-half barytes, and Hamburg white contains two-thirds barytes, and Dutch white three-fourths barytes. It makes the paint very opaque and less acted upon by sulphuric vapors. It is also used for refining sugar, enameling iron, oil clothes, paper collars, rubber, lithophane, and as a general adulterant.

Barite usually occurs in more or less nearly vertical veins, usually not more than one foot wide running through the country rock. In Tennessee the country rock is commonly limestone. The ore is often the gangue rock of lead ores. It occurs in all of the limestone counties of the State, but is workable, or has been worked in only a few. It was known in Tennessee as early as 1840, when a large body of it was discovered by Col. R. C. Morris, in McMinn County, on the point of the ridge between Mouse

Creek and Hiwassee River. In 1873 over 1,000,000 pounds of barytes were shipped from Greene, Hamblen and Monroe counties. In 1907 shipments were being made from Loudon, McMinn and Monroe counties, to the extent of 20,861 tons, and with a value of $37,138, at an average price of $1.78 a ton. Monroe County furnishes the larger part of the supply. There is only one mill in the State for refining the product, located at Sweetwater. In Smith County a vertical vein one foot or more thick has been traced for several miles, which is associated with calcite, fluorite and zinc blend. It has been dug near the Trousdale Ferry-Lebanon Road. In addition to the counties mentioned, it has been mined in Bradley, Washington and Jefferson counties.

The barytes appears to have been deposited from water solutions. In at least most cases, it appears to have been associated with lines of faulting, though it is of distinctly later origin. Near Cleveland, for example, the barytes fill groups of fissures in the Knox dolomite, with much metasomatic replacement of the rock wall. At Sweetwater the fissures are often only partly filled.

*Bauxite.*—Bauxite is an aluminum iron hydrate. The well-known Georgia bauxite, to which the Tennessee ore is similar, contains about 60% alumina, $Al_2O_3$; 32% of water, $H_2O$; 5% of silica, $SiO_2$; 2½% of titanium dioxide, $TiO_2$; 1½% of iron oxide $FeO_3$. It is used in the manufacture of alum, aluminum alloys and compounds, and the metal aluminum. Bauxite has long been known in Georgia, where it occurs in the Knox dolomite in association with faults. It is also associated with kaolin and iron ore. The mineral usually occurs as small balls, or concretions, of reddish yellow color in a similarly-colored matrix. The balls may be as large as marbles, or up to 1½ inches in diameter, and down to the size of fish-roe (oölite) or smaller. The size of the balls forms the basis of classification into pebble ore, pisolitic ore, or oölitic ore. The vesicular ore is the matrix left at the surface by the dropping out of the concretions. When the ore is structureless, or hardly shows the concretionary structure, it is called amorphous ore.

While it is probable that bauxite ore may be found in many places in Tennessee when definite prospecting of the zones of faulting in the Knox dolomite is undertaken, up to the present only one deposit has been worked. This occurs on the southeast slope of Missionary Ridge, near Chattanooga. This is doubtless the northward extension of the better known fields of Georgia.

The National Bauxite Co. was mining ore in 1907 from two pits 250 yards apart. The ore varies from the pebble variety to what is known as "block" ore, having only a small number of concretions in it. The former has the usual light color, while the latter varies from light to dark olive gray ore. The ore is rich in alumina and low in both iron and silica.

*Cement—Portland.*—For the present purpose it is sufficient to state that the Portland Cement problem is to find sufficient quantities of pure non-magnesian limestone in close proximity to suitable beds of clay or shale, near a railroad, and preferably near a cheap supply of coal. The problem is almost, or quite as much, an economic one as a geologic. The problem does not seem to have been studied with care in this State, unless by private parties, who have published no report of their findings. Lacking analyses of both limestones and shales, the best that can be done is to point out where conditions would seem to be favorable.

In a general way, it would seem that the most favorable places would be found along the east front of the Cumberland Plateau, in the Sequatchie Valley, and on the west front of the Plateau. The plateau contains coal, which could be delivered direct to the plants. The coal measures contain many beds of shale, besides the clays under the coals. While the lower flanks of the mountains are largely composed of the Silurian and Carboniferous limestones. The Queen and Crescent Railway skirts the east front of the Plateau from Chattanooga to Harriman; the Nashville, Chattanooga & St. Louis Railroad runs up the greater part of the Sequatchie Valley and reaches many points along the western escarpment. The Tennessee Central Railroad crosses both faces of the plateau. Within 50 feet of the base of the coal measures the writer has found limestone resembling structurally the Bedford stone of Indiana, though not of quite as high grade. It should prove suitable for cement. Other limestones lower down the flanks of the escarpment would doubtless be found equally suitable. Cumberland Gap is typical of many points, having limestone, coal, clay and transportation all at hand.

The second place of promise would seem to be the limestone and marble quarries of both East and Middle Tennessee, where often large quantities of refuse rock is available, or is being produced. At such places the cost of the limestone is reduced to the minimum, and there is apt to be good railroad connection.

Among the limestones of the Great Valley would be mentioned first the Lenoir limestone, just overlying the Knox dolomite. The Lenoir corresponds in position with the "Trenton" limestone, extensively used for cement in the northern part of the Appalachian Valley. Locally, it is a marble, analysis of which shows as high as 99% of pure calcite. It is closely associated with the Athens shale, which could doubtless furnish the necessary clays for mixing. In places this limestone is several hundred feet thick. Of the other limestones, most of the Chickamauga is low in magnesia, as well as limestones in the Sevier shale.

In the Central Basin are a great variety of limestones, most of which are rather high in clay, but they are in the main non-magnesian, and in many places are pure enough for cement. The Trenton limestones in the counties bordering the Cumberland River are particularly promising. Unfortunately no analyses of the limestones exist, nor has the area been especially studied for its cement possibilities. At present there is only one cement plant in the State—the Dixie Portland Cement Co., operating at Richard City, Marion County. In 1908 they produced 272,731 barrels, valued at $295,913.00.

*Cement—Natural.*—Under the preceding heading the statement was made that many of the limestones of the State are argillaceous, or contain a considerable admixture of clay. In many cases analyses would doubtless show that the relative proportion of carbonate of lime and clay is such as would make a natural hydraulic cement. Such a limestone has been used for making natural cement in Harding County, near Clifton, and the cement made there appears to have been of good grade. Among the counties which it is believed will prove to show natural cement limestones may be mentioned: Harding, Wayne, White, Decatur, Warren, Montgomery, Knox and McMinn. In Knox County cement has been made of the brown, calcereous shales.

*Chert.*—Chert is the amorphous form of quarts, or silica. It is of interest in this connection because of its value in road building. The cherts of the State (including the variety called "novaculite") probably make by far the best materials for macadam roads in the State. It is so far superior to the limestone, which at present is mainly used, that some day its use will entirely supersede that of limestone wherever it can be obtained. It appears to wear much better than limestone, as it is much harder, packs better, does not become dusty in dry weather, nor muddy

in wet weather. Where it outcrops or accumulates on top of the hills it often makes natural roads of the highest character. Where it slides down on to a road only in large pieces, or is placed on a road in that shape, without rolling or coverings, it naturally is hard on horses or tires. In Tennessee, chert occurs most abundantly in the lower part of the Knox dolomite, of Cambrian age, and in the Tullahoma formation of early Carboniferous age. (See under Novaculite for "Camden Chert"). The Knox dolomite is practically confined to the Valley of East Tennessee, where it covers large areas and is very abundant. In many cases the cherts of the lower part of the formation have been the cause of ridges, the chert being left when the limestone, or dolomite, dissolved and by its accumulating and protecting the underlying rocks formed the chert ridges. Such ridges are found all over East Tennessee, so that in most cases it would be but little more difficult to haul in the chert from the ridges and crush it in a rock-crusher for the roads in the valley than to use the limestone usually found in the valley itself.

The Tullahoma chert forms the edge of the basin of Middle Tennessee on all sides. In many places the formation appears to be solid chert for several hundred feet, the chert occurring in thin plates, continuous, though irregular, tending to break up into small pieces, or splinters. Often the formation weathers down in the hills to a depth of from 40 to 60 feet, when it can be dug out with a steam shovel, and when placed on the road this weathered chert makes an excellent top dressing, as is well seen at Centreville, Hickman County, and elsewhere. Large deposits of the material could readily be obtained for shipment wherever railroads climb or skirt the edge of the Highland Rim, as near Normandy, west of Nashville, on the Centreville Branch of the Nashville, Chattanooga and St. Louis Railroad, and on the Tennessee Central Railway east of Nashville.

*Clay and Shale.*—Tennessee, in 1908, stood twenty-fourth among the States in the production of clay products, having produced that year $1,129,174 worth of brick and tile, and $122,555 worth of pottery, a total of $1,251,728, as compared with $1,613,862 worth in 1907. The value of the clay mined and shipped is estimated at $77,680, most of that being ball, saggar and fire clay from Henry County. Brick clays are common throughout the State, as is evidenced by the fact that brick plants are maintained in about one-half of the counties of the State. Front brick

are made in Blount, Davidson, Hamilton, Knox and Madison counties; ornamental brick in Davidson and Knox; fire brick in Hamilton, Knox, Madison and Putnam counties.

In East Tennessee the residual red clays of the Chickamauga limestone make good brick, and that as well as some of the Cambrian shales are extensively used for tile. The calcareous Athens shales yield a brick clay worked at Mayesville and Knoxville, as do also the Knox dolomite, the Connasauga shale, the upper part of the Rome formation and the shales of the Bangor and Chickamauga limestone formations. Fire brick is made at Cleveland from silicous residual clays of the Knox dolomite. The red and blue residual clays of the Bangor are worked in Warren, DeKalb, Grundy, White and Van Buren Counties.

In the coal field practically all of the coal beds are underlain by clays, some of which will doubtless prove suitable for the manufacture of fire brick. No flint clay has yet been reported in this State. The coal field also contains large quantities of shale, some of which will doubtless prove suitable for paving brick and other brick. This is as yet an entirely unexploited field and practically unexplored.

The great Central Basin of Tennessee is underlain almost entirely by limestones. These yield residual clays, and doubtless exploration will reveal many shales, or other bedded clay deposits of value. In the district between the Central Basin and the Tennessee River on the west numerous deposits of fire-clay have been found in Stewart and Houston counties. The clay is grayish white and was used for many years in making fire brick for the rolling mills.

West Tennessee is abundantly supplied with clays, and some day should be the seat of a great clay industry. The fact that some of the clays of Carroll and Henry counties have been shipped to Akron and East Liverpool, Ohio, and Louisville, Ky., is evidence of their good quality. The clay immediately below the LaFayette formation yields stoneware and fire-brick clay. Many of the quarries show from 25 to 35 feet of clay. Some of the "ball" clay of Henry County has the composition of almost pure kaolin. It will run from 60% to 75% of non-plastic material. Pottery is made in a number of the counties of West Tennessee, as well as drain tile. The industry, however, is as yet in its infancy.

Kaolin has been found in small quantities in Carter and Carroll counties, and probably will be found in other counties. In

the past but little special attention has been given in the field to the study of clays of the State. It is believed that when a comprehensive study is made that this State will be shown to have an abundance of clays and shales suitable for all purposes.

*Coal.*—Tennessee ranks eleventh among the States in the production of coal. In 1907 this amounted to 6,810,243 short tons, and in 1908, 6,199,171 tons. The coal field has been estimated to have an area of 4,400 square miles. Mr. M. R. Campbell has estimated the original contents to be 25,665,000,000 short tons. The figures for production up to the close of 1908 show 90,503,772 tons taken from the ground, equivalent to an exhaustion of 135,000,000 tons, or one-half of one per cent. of the total. At the rate of exhaustion in 1908 the coal in this State, as estimated, would last 2,475 years. It may be noted, however, that the production has been increasing rapidly, as it has in other States. Taking the figures from 1850 to 1908 the production has more than doubled on the average of every ten years. From 1870 to 1900 the production increased more than three times every ten years. From 1900 to 1908 the production nearly doubled. If the production were to continue doubling every ten years, as it has in the last 70 years, the coal would be exhausted within 110 years from now.

The coal field of Tennessee is coincident with the Cumberland Plateau lying in a northeast and southwest direction across the State a little east of the center. The field has an average width of from 35 to 50 miles. It covers practically all of Morgan, Scott, Sequatchie and Bledsoe counties; the western part of Claiborne, Campbell, Anderson, Roane, Rhea and Hamilton counties; nearly all of Fentress, Van Buren and Grundy; and a part of the eastern side of Pickett, Overton, Putnam, White, Warren, Coffee and Franklin counties.

The coal-bearing rocks have a thickness of 4,000 feet at the north end of the State. To the south the whole body of rocks has been raised so that their base is about 1,500 feet above tide, and all the upper rocks have been carried away. At the north end of the State at least 50 beds of coal have been noted in Bryson Mountain, while at the south only the basal 6 or 8 remain.

Safford divided the coals into three groups, separated by widespread, massive sandstones. The lowest group he called the "Bon Air" group. This included the Bon Air, Nelson, Soddy, Lower Etna, the Castle Rock and Dade coals, worked mostly along the western edge of the basin.

The beds are all of irregular thickness, ranging from a knife-edge to 12 feet, or more, though they are seldom more than three feet over any large area. In most places not more than two of the beds are workable, and in many places all of the beds will be found to run thin. Rocks contained in this group are thin on the west side of the field, but reach a thickness of 600 to 700 feet on the east side of the field. Between this and the next overlying group is the massive Bon Air or Sewanee conglomerate, a heavy bed of sandstone 40 or 50 feet thick that makes conspicuous cliffs along the west edge of the Cumberland Plateau, or Sequatchie Valley and along the eastern face of the plateau escarpment.

The second group of coals, the "Tracy City" group of Safford, contains the Kelley, Richland or Whitwell bed, just on top of the Bon Air conglomerate; the Sewanee bed 40 to 50 feet higher; the Walker bed still higher and others above not now being worked. These coals, like those of the first group, are irregular in thickness, sometimes maintaining a thickness of five feet over quite an acreage, but usually not running over three feet, and they are too thin to work over large areas. In local basins, or "pots," they may thicken up to 7 or 8 feet, or even up to 18 feet. The rocks containing this group have a thickness of 500 to 700 feet along the eastern edge of the basin, but thin to a feather-edge on the western side of the field. Above this second group of coals is a second great sandstone, called the "Emory" sandstone, that makes a conspicuous bluff at the top of the eastern escarpment of the Cumberland Plateau from near Chattanooga at least as far north as Harriman.

The third group of coals, called by Safford "The Brushy Mountain Group," extends through rocks having a thickness of several thousand feet. Practically all of the coals being mined in the northeast part of the field belong to this group, the first two groups being below drainage in most of that area. In Bryson Mountain, Claiborne County, this group contains 50 beds with a total measured thickness of about 95 feet. Of these beds thirteen are over two feet thick, and seven were being worked in 1902-3 when examined by the writer. The beds being worked there showed an average thickness of from 4 to 6½ feet, with a range of from 3 1-3 to 9 2-3 feet. Most of them contain some partings, and that reduces the available coal by six inches to one foot. Such large numbers of coal are only found in some of the highest mountains—unreduced residuals projecting well above the

level of the Cumberland Plateau. There remain, therefore, very small areas of the uppermost coals, and even the areas of the lower coals of the group have been much reduced by erosion. The upper coals are not only thicker, but much more regular than the coals of the lower groups. The coals of this group occur only in the northeast part of the field, having been eroded from the western and southern parts, being confined mainly to the area northeast of the Queen & Crescent Railroad above Harriman.

The coals of Tennessee are of the bituminous variety, and most of them will coke, yielding from 48 to 60 per cent. The coal of the Jellico field produces an indifferent coke, but it has a wide reputation as a very high-grade household coal. The coals of the lower groups, as a rule, are cleaner and harder than the higher coals.

*Cobalt.*—Traces of cobalt in the form of asbolite, or black cobalt oxide, have been found in Hickman County. The ore occurs in managanese oxide, or wad, as an earthy black to blue mass deposited in boggy places. Mr. Lucius Brown, State Chemist, states that none found has yet analyzed over 2% of cobalt, compared with South Carolina ores that yield 24% of cobalt oxide and Missouri ores that yield 40%. The cobalt bearing wad is found at a number of points near Centreville, in Hickman County. It attracted considerable attention about 1907, through the interest of Thomas Edison, who was then looking for a supply of cobalt in connection with his studies of secondary batteries. It is possible that other deposits of wad in the State may be cobalt bearing, and ore of value may yet be found.

*Copper.*—Tennessee stands sixth among the States in the production of copper, with a production in 1908 of 19,459,501 pounds, valued at $2,568,654. In 1907 the copper output, though smaller, was valued at $3,778,623. The production comes entirely from the region about Ducktown, in Polk County, in the extreme southeast corner of the State. Two companies produce all of the ore.

The ores occur in a belt two miles wide by four miles long, lying in a northeast-southwest direction. They occur in fissure veins from a few feet to one hundred and fifty feet wide, in metamorphoric schists. The veins are nearly parallel to the schistosity dipping about 50 degrees, S. 65 degrees to 70 degrees E., apparently in slip planes of fault fissures following the foliation. The

ore, which is mainly an iron ore, contains very near 10% of copper ore, averaging about 3½% of metallic copper. The ore is chiefly pyrrhotite or magnetic pyrite, or iron sulphide, with which is inextricably mixed finely disseminated chalcopyrite, or copper pyrites. The latter, when pure, contains roundly one-third copper, one-third sulphur and one-third iron. The ore contains an average of about 31.4 pounds of copper per ton. In addition there occur small quantities of native copper, malachite, cuprite, chalcanthite and chalcocite. The latter is the black sulphide of copper, and was the common ore at first, until the workings reached below the belt of surface weathering. In the weathered belt at the surface the pyrrhotite has weathered into limonite, forming a great cap or "gossan," which has been used as a source of iron ore. The black ore near the surface was formerly thought to be the black oxide, but more recently shown by Mr. W. H. Weed to be the black sulphide. This ore is now exhausted. It had a thickness of from a few inches to eight feet or more. In addition to the copper, the mines also yield iron, as just stated. Gold, silver, and small amounts of lead and zinc ore are found.

Copper ore appears to have been known in Tennessee in 1843, but not actively mined until about 1850. In 1855 there was shipped 14,291 tons, worth, at that time, $1,000,000. After the exhaustion of the black surface ore, mining nearly ceased until 1889, when the Marietta and North Georgia Railroad entered the district and mining took a new lease of life. In 1899, the Tennessee Copper Company began the opening up of their mines, which is the beginning of the present development. In 1908 several of the mines were down to the depths of from 700 to 800 feet or more, and some of the levels have followed the vein three thousand feet or more and are still in ore. Recently an expensive plant has been installed at Ducktown to conserve the sulphur fumes formed in the reduction of the copper and convert them into sulphuric acid.

*Copperas.*—Copperas is iron sulphate. It occurs in nature through the action of the atmosphere on pyrite. It is found in many of the "rock-houses" of Tennessee, especially where the underlying shale is the Chattanooga black shale, which commonly contains pyrite. It only accumulates where it is sheltered from the weather.

Today practically all of the copperas of commerce is made ar-

tificially. At one time it was manufactured extensively in Ducktown from the refuse of the copper mines, but probably all of it is obtained now as a by-product in the manufacture of wire and sheet steel.

*Dolomite.*—The Knox dolomite of East Tennessee has been used very extensively for abutments of railroad bridges and similar structural work. It is readily cut and dressed, and due to its firm, fine structure, is capable of standing great weight. It splits readily along bedding plains six inches to three feet apart, and resists frost and heat well.

*Epsom Salts.*—The mineral epsomite is found at many points in the State associated with alum and copperas. It does not appear to have been made use of at all in a commercial way.

*Fluorspar.*—Fluorite, or, as it is commonly known, "Fluorspar," is calcium fluorite. In its purest form it is used in the manufacture of opalescent glass, enamels, agate ware, hydrofluoric acid and other compounds of fluorine. Slightly lower grades are used in the manufacture of open-hearth steel, to increase the fluidity of the slag. Still lower grades are used in foundry work. The use of hydrofluoric acid in etching glass is well known.

Tennessee has never been a large producer of fluorspar. From 1902 to 1906 small quantities were mined in Smith, Trousdale and Wilson counties. The ore is high-grade, and occurs in fissure veins intersecting limestones of Ordovician age. It is said that lumps of pure fluorspar weighing 1,500 pounds have been taken from these deposits. No igneous rocks have been reported as occurring in the neighborhood of these veins, as they do in Kentucky and Illinois. In some cases the fluorspar is associated with barite.

*Gas.*—(See under heading "Oil").

*Glass Sand.*—Sandstones and conglomerates of the coal field are often made up of white sand and pebbles. When quarried, crushed, separated and washed, they are suitable for the best grades of plate-glass. Some have been shipped to Indiana for use in the glass works of that State. Good sand is found at Coal Creek, in Anderson County, and glass has been made in Knoxville from sand obtained on the opposite side of the Holston River. Benton County furnishes saccaroidal sandstone of dazzling whiteness that should be suitable for the manufacture of glass.

*Gold.*—Gold has been found in Tennessee only along the eastern edge of the State in the Cambrian or pre-Cambrian rocks on

the western flank of the Great Smoky Mountains. Placer gold has been found in the creeks a few miles east of Montvale Springs and back of Chilhowee Mountain in Blount County; in Polk County; and on Citico Creek, Cane Creek, the headwaters of the Tellico River and on Coker Creek, in Monroe County. The last locality has furnished nearly all of the gold found in the State, amounting to probably not over $200,000.

The Coker Creek (Coca or Coqua Creek of the old reports) deposits embrace a strip of country eight or nine miles long by two or three wide. Gold was first discovered here in 1831, followed by the usual "rush," during which the whole region was thoroughly prospected. The gravels at first yielded an average of $2 a day, but gradually decreased to a yield of about fifty cents a day. The largest piece reported found was worth about $20. Later a 6-inch vein of gold-bearing quartz was found on Whippoorwill Branch of Tellico River, and has been worked some. It is more than probable that some day, other, and probably richer, quartz veins will be found. In 1908 Monroe County yielded 21.61 ounces. In the same year 149.33 ounces were obtained from the copper ores of Ducktown, in Polk County, as a by-product.

*Granite.*—In Tennessee granite is confined to the western slope of the Great Smoky Mountains. At present no granite is being quarried for commercial shipment in the State. Portions of the Max Patch granite, marked by red feldspar, are very ornamental, as are the porphyritic masses in that granite. These beds are often heavy enough to yield large blocks of building stone, though much of the granite tends to be gneissoid. The Cranberry granite is lighter in color and fairly uniform in texture. It would be suitable for many purposes. Large blocks of granite were exhibited at the Centennial Exposition, Nashville, 1897. Granite is found in Johnson, Carter, Unicoi, Greene, Cocke, Sevier, Blount, Monroe and Polk counties.

*Green Sand.*—Associated with the Selma clays are often found beds of greenish sand. The color is due to the presence of glauconite. Analysis of this green sand usually shows it to contain a considerable percentage of lime, often an appreciable amount of phosphorus. Such a calcereous sand has been called a marl. It is of value as a fertilizer, depending on the amount of lime, phosphoric acid and potash present. It occurs in West Tennessee. Samples showed on analysis 50 per cent. of silica, 10 per cent. potash and phosphoric acid, 2 to 10 per cent. of lime carbonate.

*Gypsum.*—No workable deposits of gypsum have yet been found in Tennessee. It occurs in small quantities in many of the caves of the State, often making handsome cabinet specimens; sometimes as crystals, or transparent clevage plates; sometimes as rosettes, etc. Small, irregular masses of snowy gypsum are common in cavities in many of the limestones. In some cases these might be separated from the limestones in connection with the quarrying of the whole, but in no place that the writer has seen yet are they in a sufficient quantity or size to make them the subject of commercial exploiting.

*Hydraulic Rock.*—(See cement).

*Iron.*—Tennessee ranks eighth in the production of iron. In 1907 she produced 269,182 tons of hematite, 544,508 tons of brown ore, a total of 813,690 tons, with a value of $1,352,131. In 1908 the production was somewhat less, amounting to 226,038 tons of hematite and 409,305 tons of brown ore, a total of 635,343 tons, valued at $876,007. In the production of pig iron the State ranked seventh in 1907 with a production of 393,106 long tons, valued at $7,542,000. In 1908 the production was 290,826 tons, valued at $4,011,000.

It is impossible to estimate correctly the quantity of iron ore now available, or to be available in the future. Very roughly it has been estimated that Tennessee has about 500,000,000 tons of iron ore, of which 100,000,000 tons are now available, and the other 400,000,000 will became available under more favorable mining and market conditions.

The ore occurs in four belts: First—An eastern belt through Johnson, Sullivan, Carter, Washington, Unicoi, Greene, Cocke, Sevier, Blount, Monroe, McMinn and Polk counties, containing limonite, hematite and magnetite. The ores are usually in irregular masses of limited extent, associated with the older rocks and the metamorphosed rocks.

The limonite occurs in compact form, in shapeless masses, in the foothills, spurs, coves and valleys, mingled with clay and cherty masses. When pure it contains 59.52% of metallic iron. The hematite, anhydrous oxide of iron, is of the hard variety. It is found in massive layers in the valley of Stony Creek, in Carter County; in vein-like, nearly vertical masses in Sullivan County; in compast masses in Monroe and Cocke counties; in angular nodules on Cross Mountain; in nearly cubical masses in McMinn County, east of Athens; in Ordovician strata in Loudon County.

Magnetite, the black, magnetic oxide, containing 72% of iron when pure, occurs in many of the older rocks in the mountain spurs of Carter County, where they run down into Crab Orchard Valley.

Second—A belt along the east face of the Cumberland Table Lands and in the Sequatchie Valley. The ore in this case is mainly a red, fossiliferous oölitic hematite ore, known as "Clinton Ore." It has been mined extensively in Hamilton, Bradley, James, McMinn, Meigs, Rhea, Roane, Henderson, Campbell, Union, Grainger, Claiborne, Hancock, Marion, Sequatchie and Bledsoe counties. The ore occurs as a bedded deposit with much regularity, having a thickness of up to six feet. The leached ore at the surface yields about 56% of iron, though the hard, unweathered ore yields much less.

It has been estimated that the ore has an average thickness across the State of 20 inches. In many places there are several beds, though usually there is one bed of importance. This may vary from a few inches to two or three feet thick, occasionally swelling out to six feet. The Clinton ore is also found in many of the ridges east of the Plateau escarpment, though most of the mining has been done among the low foothills just at the foot of the escarpment. The ore should outcrop all along the east side of the Sequatchie Valley. It is hidden by faults on the west side of the Valley. Apparently the same ore was seen by the writer in west Davidson County 5 feet thick, and it is reported that it is extensively exposed west and north of Nashville.

The third belt is co-ordinate with the coal field, and the ores consist of "clay iron stone" nodules in the shales of the coal measure rocks.

The nodules, balls and flattened concretions usually carry 30% to 33% of metallic iron. They occur from the size of small pebbles to masses weighing a ton or more, disposed in layers interstratified with the shales. Much of this ore has been noted below the Wiley coal band in Anderson County and elsewhere. A layer of black band, or coaly carbonaceous iron ore, 6 to 12 inches thick, has been noted near Beersheba Springs, and some limonite is found scattered over the table-land.

The fourth belt is in western Tennessee, covering an area 50 miles wide, or 5,400 square miles. It lies in the counties of Lawrence, Wayne, Hardin, Lewis, Perry, Hickman, Humphreys, Dickson, Houston, Montgomery and Stewart east of the

Tennessee River, and Benton and Decatur counties on the west of the Tennessee River. The ores in this belt are liminite, with some hematite and turgite, and occur associated with the chert and clay from the decomposition of the St. Louis limestone. These deposits in places have a thickness of up to over one hundred feet. The ore makes up from one-half to one-fourth, or less of the mass.

These ores have never been adequately prospected, but sufficient work has been done to show large quantities of ore. The ore typically occurs as layers in intermingled chert and clay, or as "nests," or large, irregularly-shaped masses, or in lumps down to the size of a walnut, usually underlying an over-burden of clay, chert or gravel.

Iron making in Tennessee dates from 1790, when a bloomery was built at Embreeville. In 1856 there were 75 forges and bloomeries, 71 furnaces (using charcoal, and varying in capacity from 5 to 18 tons a day), and 4 rolling mills.

In 1908 there were 67 iron mines being worked by thirty-eight companies, with 17 furnaces in active operation, all but one of them using coke for fuel; seven furnaces were not running during that year.

*Kaolin.*—(See clay.)

*Lead.*—Lead ore has not yet been found abundantly in Tennessee, though most of the counties have reported some lead. It is frequently found in the Knox dolomite, associated with zinc, and probably most of the production has been from the zinc mines. Galena, or lead sulphide, is found in true veins in grains and lumps, in Union County, and disseminated in grains through the rocks of Bompass Cove in Washington County, and as irregular masses or benches in McMinn County. Veins are known in Monroe, Bradley and Jefferson counties, all of which have been worked. Many veins have been found and opened in the Central Basin, but none have proved profitable. Mines have been opened in Davidson County and in Williamson County, near Nolensville. Fine specimens have been found in Hickman, Henry and other counties.

Lead has been mined with zinc on Straight Creek, in Claiborne County, five miles southwest of New Tazewell. It is found in minable quantities in Blount County and in Bradley County, 20 to 30 miles east of Chattanooga. It has been mined for some years at Blue Springs, six miles south of Cleveland, and at the Cedar Ridge mine encouraging prospects are found.

The ores in Tennessee are the sulphide—galenite, or galena, occurring granular, or massive granular form, showing on analysis up to 74% of lead; and cerussite, or lead carbonate, a secondary form derived from the original galena, occurring only in narrow bands at the top of the undecayed limestone. In 1908 no lead was mined in Tennessee, though some lead had been mined for several years preceding, the amount varying from 15,000 pounds to over 200,000 pounds, the latter in 1906, when the output was valued at over $10,000.

*Lignite.*—Lignite is a form of coal in one of its earliest stages. It is brown or black, sometimes appearing compact like coal, sometimes like a mass of decayed vegetation. It is found extensively in the Eocene deposits of West Tennessee, the beds being interstratified with clay and sand, and varying from a few inches up to four or five feet in thickness. As a rule the beds do not seem to have much lateral extent. Recently (August 29, 1910) a 20-foot bed of lignite is reported to have been found near Cottage Grove, in Henry County. The papers of Sept. 5, 1910, report the discovery of "genuine coal" two miles southwest of Burleson, Tipton County. This is doubtless lignite, and indicates the close resemblance to bituminous coal. The beds have been found extensively in Obion, Dyer, Lauderdale, Tipton, Shelby and Johnson counties, along the escarpment of the Mississippi bottoms. Attempts to use the lignite of West Tennessee as fuel have not been successful in the past. New interest has recently been taken in the subject through the work of the National Bureau of Mines in showing the availability of lignite for power when converted into producer gas and used in the gas engines.

*Limestone.*—A majority of the rocks of this State are limestone. They are in every shade of color from gray to black, and in every variety from pure, heavy-bedded limestone to very impure laminated, shaly, or sandy limestones that soon crumble when exposed to the weather. They are put to a variety of uses, from building roads to lining fine buildings. Some are burned to lime. Twelve counties in the State in 1908 furnished 69,754 tons of lime, valued at $224,236. The lime was used in alkali works, in buildings, for fertilizer, for paper mills, sulphate and soda-pop mills, sugar mills, tanneries, etc. In 1908 the total output of limestone in Tennessee was 837,893 tons, valued at $500,677 (not including marble); of this value $8,103 was for rough building stones, $3,500 for dressed building stones, $315.00 for

paving stone, $2,999 for curbing, $16,609 for rubble, $13,591 for rip-rap, $205,275 for crushed stone for road making, $63,634 for railroad ballast, $89,001 for concrete, $16,065 for flux, and $1,585 for miscellaneous uses.

The Clifton (Niagura) limestone has been extensively quarried for building stone, curbing, etc., at Goodlettsville, Newsom and elsewhere, though large quantities of Bowling Green (Ky.) stone are now being imported into the State, and many of the quarries are devoting their time to crushing the rocks for roads. It is hoped in time to find oölitic limestone of sufficiently high grade, and under favorable conditions for quarrying and marketing to supply the home market, and displace the Bowling Green stone.

*Lithographic Stone.*—The limestones of the Mississippian or Lower Carboniferous tend locally to have the compact structure necessary for lithographic work. Such stone has been found in Indiana, Kentucky and Tennessee. As a rule the difficulty has been to find stone sufficiently free from flaws over a large enough surface to be usable. In Tennessee some very good stone has been found near Algood, in Putnam County. The Dunbar Lithographic Stone Co. have taken out some, but little work has yet been done. While the stone gives some promise, it has not yet yielded large sized stones, such as the market demands. The stone occurs just under the base of the coal measures, and should be looked for all around the western edge of the Cumberland Plateau and up the Sequatchie Valley.

*Manganese.*—Manganese in the form of oxides occurs commercially in northeastern Tennessee. The principal deposits are in Shady Valley, Johnson County; near Unicoi, Unicoi County; near Newport and Del Rio, Cocke County. The ores occur in the lower part of the Shady Limestone, or at the contact of that formation with the Erwin Quartzite. They are found in variegated clays, and are generally associated with brown iron ores. The ore is in the form of hard nodules, or irregular masses, mainly of psilomelane, or in the form of irregular pockets of soft pyrolucite, or wad. The ore also occurs near Morristown, in Hamblen County, associated with the brown iron ore; near Sweetwater, Monroe County, in the red residual clays from the Knox dolomite. Small quantities are found in the Chilhowee Mountains, in Hickman County, and elsewhere. As a black stain on the rocks, manganese oxide occurs somewhat as does iron in staining rocks all over the State.

It has been mined some near Elizabethton, in Carter County, and in other counties of East Tennessee. No maganese was produced in the State in 1908. In 1907 100 long tons were produced, worth $1,500, or $15 a ton. The maximum production in Tennessee was, in 1894, 922 tons. The total production has been 2,475 tons.

*Marble.*—Marble is the name commonly applied to a crystalline limestone that will take a good polish, and be attractive when polished. The name is also applied to many other non-calcerous stones—serpentines, breccias, conglomerate, etc. Tennessee is abundantly supplied with marbles of many and high grades. In 1908, the State stood third among the States of the Union, with a production worth $761,222. The present commercial output of Tennessee comes almost entirely from one bed, the Holston marble, a bed in the Chickamauga limestone, and all from East Tennessee, and mostly from Knox County, though Blount County is also a large producer. The bulk of this stone is used for interior decoration, to which purpose it is highly suited.

The main marble stratum has a thickness of 300 to 400 feet, and up to 650 feet, though usually not over 50 feet is workable at any one point. The bed shares in the usually folded condition of the rocks of East Tennessee, sometimes pitching steeply and making a narrow outcrop, sometimes outcropping broadly with a low dip. In general it forms a narrow, irregular line of outcrop across Hawkins, Hancock, Hamblen, Grainger, Claiborne, Union, Knox, Sevier, Blount, Roane, Loudon, Monroe, and McMinn counties. The marble varies in color from cream, yellow, brown, chocolate and red, to pink or blue, in endless variety. The color results mostly from impurity in the form of iron. The color occurs in the rock in a variety of ways; sometimes scattered regularly, sometimes irregularly, often fantastically. Tests of the pure limestone show it to be very high in crushing strength—averaging 16,000 pounds per square inch—and to have a high resistance to absorption of water. The colors and character vary from quarry to quarry, and sometimes within a single quarry.

In addition to the Holston marble, a similar marble is extensively developed in the lower part of the Sevier shale in Sevier and Knox counties. This marble has been quarried to a small extent. A black marble is found in Washington, Green, Sevier, Blount, and other counties, in the eastern part of the State; brown and flesh-colored marbles are found in Jefferson and Ham-

blen counties; fawn-colored marble in Lawrence County, on the Highland Rim, and gray and red-variagated marble in Franklin, Lincoln and other counties of the Central Basin. Coarser marbles occur in Benton, Hamilton, and Henry counties.

A magnesian marble of impure quality occurs in the Knox dolomite. In Blount, Monroe and McMinn counties are conglomerate and breccias that have been successfully used as marble, the polished block resembling mosaic work. Tennessee marble was first used extensively in 1844 in the National Capitol at Washington, and afterward, in 1852, in the State Capitol at Nashville, since when there has been a steady demand for it. It has also been used extensively as an outside building material, as in the erection of the custom-houses at Knoxville, Chattanooga and Memphis.

*Marl.*—(See Green Sand).

*Millstone grit.*—Millstone grit as a commercial stone has practically passed away, its use having long since been abandoned, except in an occasional little neighborhood mill run by water-power. Stones suitable for millstones are abundant in the State. Among those that have been used are quartzite and gneiss, found in Johnson and Carter counties, partially weathered chert from the Knox dolomite from Claiborne, Jefferson and Knox counties (a true buhrstone), a silicified shell bed coming just under the Chattanooga Black shale, said to be equal to the French buhr, from Trousdale and Coffee counties, and fine-grained conglomerates from the coal measures.

*Minerals.*—The following list of minerals have been noted in Tennessee:

| | | |
|---|---|---|
| Albite, | Bauxite, | Coal, |
| Alisonite, | Bornite, | Copper, |
| Allophane, | | Copperas, |
| Alum, | Calamine, | Cuprite, |
| Amphibole, | Calcite, | |
| Anhydrite, | Celestite, | Diallage, |
| Apatite, | Cerussite, | Dolomite, |
| Asbolite, | Chlorite, | Ducktownite, |
| Azurite, | Chalcanthite, | |
| Asphaltum, | Chalcopyrite, | Epidote, |
| | Chalcotrichite, | Epsomite, |
| Barite, | Calcedony, | |

Fluorite,

Galenite,
Garnet,
Gold,
Graphite,
Gypsum,
Glauconite,

Harrisite,
Hematite,
Hornblende,

Jasper,

Lignite,
Limonite,

Magnetite,
Malachite,
Melaconite,
Melanterite,
Molybdenite,

Nitre,
Nitrocalcite,

Orthoclase,

Petroleum,
Psilomelane,
Pyroxene,
Pyrite,
Pyrrhotite,
Prolusite,

Quartz,

Rahtite,
Rutile,

Siderite,
Sphalerite,
Sahlite,
Smithsonite,
Sulphur,

Tremolite,

Wad,

Zoisite.

*Metallic Paint and Mortar Colors.*—Many low-grade ores, as well as some of better grade, are mined not for the metal they contain, but as paint, or for coloring mortar. The oxides and carbonates of iron, zinc and lead are so used. In Tennessee, Bradley, Cheatham and James counties supplied such material to the extent (in 1908) of 1,300 tons, and value of $16,100.

*Mineral Springs.*—Tennessee is blessed with a great abundance of mineral springs, in many cases situated amid attractive scenery, and supplying a great variety of chemical constituents. It would not be possible, in brief notice such as this, to even list all of the springs. In most cases the springs, whose locations are noted beyond, are supplied with hotels, ranging from the plainest, unpainted board buildings, to handsome modern hostelries. In many cases the hotels are surrounded by cottages. The following list is, in the main, based on one published by Crook's "Mineral Springs of the United States," with the addition of some well known springs omitted in that list. The list, however, makes no pretense of being complete, even as regards springs which serve as watering places, and which have hotel and other accommodations. At a later time a special bulletin will be gotten out, describing the various springs, which either serve as summer resorts, or whose waters are sold or otherwise extensively used. The list of springs is followed by the chemical analysis of a few of them, which will serve to show their chemical character.

## SOME OF THE MINERAL SPRINGS IN TENNESSEE.

*Anderson County.*—Oliver Springs; 9 springs; hotel.

*Bledsoe County.*—S. Saratoga Springs (P. O. Pikeville); hotel and cottages; 2 springs.

*Blount County*—Melrose Springs (P. O. Maryville); 4 springs; 8 miles of Maryville; elevation, 1,500 feet A. T. (above tide). Montvale Springs; hotel and cottages; ele. 1,300 ft. A. T. Allegheny Springs; chaly. (chalybeate) and sul. (sulphur); 14 miles south of Maryville.

*Campbell County.*—Eagle Bluff Springs; 1 mile north of Jacksboro.

*Clay County.*—Wood Springs.

*Cocke County.*—Patterson Springs, near Birdsville.

*Coffee County.*—Pylant Springs.

*Cumberland Springs.*—Howard Springs (P. O. Crossville); 3 miles west of Crossville; 600 gallons per hour; 1900 ft. A. T.

*Cheatham County.*—Kingston Springs; sul. and chaly.; Willow Brook; Craggie Hope.

*Davidson County.*—Crocker Springs; 2 springs; 12 miles west of Nashville. Nashville Sulphur Spring (artesian). Lockeland (old), Nashville. Deep Cave, Nashville. Pioneer Lithia, Nashville. Richardson's Lockeland, Nashville. Buena Vista, Nashville.

*Decatur County.*—Dixon Springs (P. O. Perryville); 3 miles from Perryville.

*Franklin County.*—Cascade Springs; alk. (alkaline) and sul. Estill Springs; alk., sul. and chaly. Graham Springs; calc. (calcareous), alk, and sul. Hurricane Springs; alk. and sul. East Brook Springs (P. O. Estill Springs).

*Grainger County.*—Mineral Hill Springs (P. O. Bean Sta.); 10 miles from Morristown. Tate Springs (P. O. Tate Springs); 2 modern hotels and cottages; 1,400 feet. A. T.

*Giles County.*—Elkmont Springs, chaly.

*Gibson County.*—Gibson Wells.

*Grundy County.*—Beersheba Springs (P. O. Beersheba); 12 miles from McMinnville.

*Hardin County.*—Pickwick, White and Red Sulphur Springs.

*Hawkins County.*—Wright's Epsom Lithia Well (3 miles from

Mooresburg). Mooresburg Springs, chaly. Galbraith Springs (P. O. Galbraith Springs); 4 springs; 9 miles from Russellville.

*Henderson County.*—Hinson Springs (P. O. Hinson Springs); 5 springs; 24 miles east of Jackson.

*Hickman County.*—Primm Springs. Beaver Dam Springs; sul. Bon Aqua Springs; calc. and sul.

*Jefferson County.*—Conwood Springs; chaly. and sul.

*Knox County.*—Dixie Springs; artesian well.

*Lawrence County.*—Wayland Springs; sul. and chaly.

*Macon County.*—Red Boiling Springs (P. O. Red Boiling Springs); 3 springs; hotel; baths; 1,200 feet A. T. Upper Red Boiling Springs (P. O. Red Boiling Springs); hotel, baths, boarding houses; 25 miles by stage from Carthage.

*Montgomery County.*—Idaho Springs, St. Bethlehem, near Clarksville.

*Morgan County.*—Morgan Springs.

*Putnam County.*—Draper Springs; chaly. and sul. Bloomington Springs.

*Rhea County.*—Rhea Springs; alk., chaly. and sul. Morgan Springs; chaly.; 1,934 feet A. T.

*Robertson County.*—Hygeia Springs. Edward Springs, sul.

*Sevier County.*—Glen Alpine Springs (P. O. Newport); 12 miles west of Newport; 4 springs; 60 gallons per hour; 3,000 feet A. T. Line Springs (P. O. Line Springs); 30 miles east of Knoxville; 2,000 feet A. T.

*Sumner County.*—Castallian Springs.

*Sullivan County.*—Avoca Springs (P. O. Bristol); 6 miles from Bristol; 3 springs, flowing 30, 10 and 2,000 gallons an hour; 1,650 feet A. T.

*Tipton County.*—Glen Springs (P. O. Atoka); 7 miles from Atoka; 90 gallons per hour.

*Unicoi County.*—Unaka Springs (P. O. Unaka Springs); 9,000 gallons per hour; 2,000 feet A. T.

*Van Buren County.*—Robinson Springs (P. O. Chalybeate); cottages; 16 miles from McMinnville; 1,750 feet A. T.

*Washington County.*—Austin Springs; 5 miles Johnson City.

*Williamson County.*—Aqua Sanitas, Franklin. McEwen Springs, Franklin. Fernvale Springs (P. O. Fernvale Springs); 13 miles from Franklin; 1,400 feet A. T.

*Warren County.*—Faulkner Springs. Nicholson Springs.

*Wilson County.*—Horn Springs (P. O. Lebanon); 8 springs; 5 miles west of Lebanon. Hamilton, Horn Springs.

ANALYSES OF TENNESSEE SPRINGS WATER.

Grains in one Gallon.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Alumina | 2.00 | .30 | .03 | | .50 | .12 | | |
| Aluminum sulphate | | | | | | | | .15 |
| Calcium carbonate | 3.20 | 14.90 | 3.84 | 9.64 | 13.26 | 9.64 | 21.56 | 7.03 |
| " nitrate | | | tr. | | | | | |
| " phosphate | | | tr. | .01 | | | 1.14 | |
| " sulphate | 4.80 | | .92 | | 74.21 | 15.36 | 160.66 | 31.16 |
| Iodide | tr. | | | | | | | |
| Iron carbonate | | .60 | .41 | .54 | 2.40 | | | .10 |
| " chloride | | | | | | | 2.99 | |
| " oxide | 11.20 | | | | | .08 | | |
| " sulphate | 6.40 | | | | | | | |
| Lithium carbonate | | | tr. | | | | | |
| " chloride | | tr. | | | | | | |
| Magnesium carbonate | | 23.30 | .47 | 7.10 | | | | 5.75 |
| " chloride | | .54 | | | | | .62 | |
| " sulphate | 11.20 | 6.18 | | | 12.00 | 7.97 | 32.91 | |
| Nitric Acid | | | | | | | .02 | |
| Potassium carbonate | | | | .05 | | | | |
| " chloride | | | | | | | | .44 |
| " nitrate | | .60 | | | | | | |
| " sulphate | | | .16 | .27 | | | 1.54 | |
| Silica | | .36 | .68 | 1.38 | | .58 | 2.70 | .47 |
| Sodium carbonate | | 146.91 | | 1.58 | | | | |
| " chloride | .80 | 110.35 | .07 | .16 | 1.96 | 10.75 | 40.27 | 43.87 |
| " sulphate | 2.40 | 9.70 | .26 | | 4.51 | 1.03 | 8.50 | |
| Loss | 4.00 | | | | | 2.31 | | 2.42 |
| | 46.00 | 313.74 | 6.84 | 20.75 | 108.84 | 47.82 | 272.91 | 91.39 |

1. Austin Springs, Washington County. Alpheus & Dove, Analysist.
2. Dixie Spring, Knox County. J. W. Slocum, Analysist.
3. Fernvale Spring, Williamson County. W. A. Noyes, Analysist.
4. Glenn Spring, Tipton County. W. T. Lupton, Analysist.
5. Montvale Spring, Blount County. S. B. Mitchell, Analysist.
6. Red Boiling Springs (No. 2), Macon County. John T. Anderson, Analysist.
7. Tate Spring, Grainger County. T. S. Andisell, Analysist.
8. Unaka Spring, Unicoi County. Safford & Wharton, Analysist.

In 1908, $60,129 worth of spring water was reported sold, about three-fourths for medicinal purposes, and the rest for table use.

*Mortar colors.*—(See mineral paints).

*Nitre, or Saltpeter.*—Though not an object of commercial interest today in Tennessee, nitre has been mined in this State during war times. Many of the caves in the limestone region contained earth in which is lime saltpeter (lime nitrate, or nitro calcite). During the War of 1812 especially large amounts of

this earth were obtained from the caves, bleached, and the lye evaporated, the nitre being used for gunpowder. Some was also obtained during the Civil War.

*Novaculite.*—The writer here uses the term "novaculite" for what has been called "Camden chert" purely on its general resemblance to the well-known Arkansas novaculite, without having made either a microscopical or chemical examination. The stone has the same fine-grained texture (under the hand lens), with the color, etc., of the Arkansas stone. It differs in being highly fossiliferous, while no fossils have ever been found in the other stone. Whether it has any of the valuable qualities of the Arkansas stone as a whet-stone remains to be seen. At present its chief value is for making macadam roads, for which, when properly screened, it can hardly be equalled. Like the cherts, it tends to break down into small fragments, or splinters, that mat together, so that even when being handled in a wagon it is often necessary to use a pick to loosen the mass so that it may be handled. The novaculite of Tennessee occurs in a narrow strip on the west side of the Tennessee River, especially in Benton County. At Camden, it shows a thickness of 50 feet or more. It is being dug and extensively shipped from two pits just east of Camden. What has been said of the superiority of chert over limestone for macadam roads is equally true for novaculite, if not more so.

*Oil and gas.*—Tennessee has not as yet developed any large oil or gas pools. In 1908 this State reported no oil production, but four producing gas wells yielded 2,200,000 cubic feet. Many wells have been drilled for oil and gas, scattered over the State. Nearly all of these have had a show of oil or gas, and a few for a time produced well, and gave promise of a field. But ultimately all have played out without the hope being realized. About 1865-67 some wells were drilled on Spring Creek, in Overton County, that produced some oil. The wells were at first only from 19 to 52 feet deep, but were later deepened from 75 to 600 feet, as they ceased to flow at the shallower depths. The Newman well obtained about 2,000 barrels at 19 feet; when the oil failed, it was drilled down to 52 feet, when an additional 2,000 barrels were obtained. The Douglass well, 75 feet away, was 75 feet deep, and produced 30 barrels a day for a time; the Hoosier well, 250 feet from the last named, produced 5,000 barrels at the rate of 50 barrels a day, from a depth of 35 feet. After

giving out it was deepened to 70 feet, again striking some oil. Where the wells were drilled the Chattanooga black shale is about 200 feet deep. It is apparently the source of the oil here as well as elsewhere. Wells drilled deeper fail to find oil. It has been estimated that somewhat over 10,000 barrels were obtained altogether here. This was hauled to Butler's Landing, on the Cumberland River, and to McMinnville. At various times since then attempts have been made in the same region to obtain oil and gas, resulting in several small wells. Some drilling is still in progress in the region, though apparently not getting oil in any quantity.

In addition to the preceding, several thousand barrels of lubricating oil were found near Algood, in Putnam County, on the Douglass property. Some oil was also obtained on Eagle Creek, in Overton County, and about 200 barrels on Jones Creek, in Dickson County, at a depth of 132 feet.

Interest in oil was renewed in Tennessee in 1891 by the striking of oil on the Rugby lands, two miles west of Glenmary, in Scott County. The oil was green in color, of 42° specific gravity Baumé. It was found at a depth of 1,266 feet. The well filled with oil for 164 1-2 feet up. The well was put down on Mr. W. G. Strubble's land. The Forest Oil Company put down two other wells on this same land, striking oil at 1,340 feet and 1,235 feet, but in smaller quantities. In 1895 two wells were drilled, getting green oil of 38.6° and 43.6° Baumé, and free from sulphur. One, which came in in July, flowed some 4,000 barrels, and the other some 50 barrels.

In January, 1896, a well at Bob's Bar, in Fentress County, 276 feet deep, came in flowing 50 barrels an hour. After 14 hours the oil caught fire and burned up the rig. In November the well was refitted and put to pumping, and up to 1900 it had yielded 20,080 barrels, making 17 to 20 barrels a day, pumping 7 to 9 hours. The National Transit Company built two tanks of 40,000 barrel capacity, and the output went into these tanks, not being marketed, for lack of transportation, for the location is 30 miles from a railroad. Of the numerous wells drilled in that region, the Reagan well in 1899 had a production of 2 barrels a day; the Rock House well flowed a little oil, and one or two others showed some oil or gas. After extensive drilling, all of the large oil companies abandoned the field and surrendered thousands of leases, some of the companies having expended as

much as $50,000. Wells were drilled in Overton, Fentress, Pickett and Scott counties, to a depth as great as 2,793 feet. The yield of Bob's Bar is of light green color, with a specific gravity of 0.846 (35° Baumé), and free from grit.

The production of natural gas in Tennessee has so far been very slight. Many of the wells obtain a little gas, but there have been only a few that have obtained enough to pay for making any attempt to use it. A well in Franklin County has been used to light and heat one dwelling and run a six horsepower engine. The Battey well in Fentress County produces some gas. At a few other points enough gas is produced to light one or two dwellings, or to run a flambeau. In southwestern Davidson County a gas spring was ignited and burned for six months. Oil and gas seepages are abundantly reported.

The problem of finding oil and gas in Tennessee is one in which there appears to be great interest. A study of the facts shows a wide distribution of oil and gas. Most wells drilled have found at least a show, and many oil and gas springs indicate the abundance of those substances. Closer study shows a close association between the oil and gas, and the Chattanooga black shale, that is widely distributed over the State. The black shale is well known to contain a large amount of bituminous matter, which may be distilled off as oil or gas, leaving an asphaltic residual, which may run down into the underlying rocks. Such asphaltic streaks occur in the "blue phosphate" rock. On Blue Buck branch of Swan Creek, in Hickman County, it has run down into the crevices of the underlying limestone to a distance of twelve feet. In Overton County wells are found to have obtained their oil from strata within 150 feet above the black shale. The burning gas well in southwestern Davidson County is about 50 feet above the black shale, and so it goes. Unfortunately, in this State, the black shale is not overlain by an open, porous bed that would serve as a resevoir for the oil and gas. The Tullahoma chert is close grained, though the crevices may contain some oil, as apparently they have at Netherland. The black shale has been entirely removed from the Central Basin, but underlies all of the Highland Rim, in the escarpment of which it outcrops. It is, therefore, a possible source of oil under all of the Highland Rim and the Cumberland Plateau. In that area attention should first be given to any structural anticlines that may be found, especially to the northward extension of the Se-

quatchie Valley anticline, where well under cover, or northeast of Crab Orchard on the Tennessee Central Railway.

A second possible source of oil and gas in Tennessee (as judged by the experience of other States) is at the top of the Trenton limestone, from which is obtained the oil and gas of the Lima-Indiana field. Up to date this horizon has not proved productive in this State. Whether from lack of suitable reservoir for the oil, or for lack of oil is uncertain; the evidence would suggest the correctness of the first view. The horizon is lacking over most of the Central Basin. It outcrops in the foot of the Highland Rim escarpment and underlies the Rim and the Cumberland Plateau. As before, any broad, minor anticlines should be tested first. A third possible source of oil and gas is in the rocks of more recent age in West Tennessee. The oil and gas of the Gulf Coastal Plain in Texas, Louisiana and Oklahoma suggest the possibility of finding oil and gas in similar strata in this State. In a general way a north-south belt through the middle of West Tennessee would seem to offer the best chances.

From what has been said, it is evident that the Central Basin and the Valley of East Tennessee, are not recommended as areas offering favorable chances, though it can not be asserted that no oil or gas will be found in either district. If structure alone be considered, Murfreesboro would be an ideal spot, but unfortunately the rocks lying below most of the Central Basin, though often tested, have not as yet yielded oil anywhere in the Appalachian field. In the same way experience in drilling east of the Allegheny front, or Cumberland escarpment, from Pennsylvania to Alabama, has so far given only negative results. To the knowledge of the author, not a single well of the many drilled in that long belt has ever paid for itself.

*Phosphate.*—Tennessee ranks second in the production of phosphate rock, standing next to Florida. In 1907 the total production was 638,612 long tons, valued at $3,047,836. Four main types of phosphate rock are found: The "brown," from the leaching of limestones; the "blue and gray," bedded deposits; the "nodular," in shales; and the "white," probably redeposited from solution. The phosphate deposits appear to be confined to the western and northern parts of the Central Basin, and adjoining territory extending locally across the Tennessee River. The largest deposits have been found in Maury, Hickman, Lewis, Marshall, Perry, Williamson, Giles, Sumner and Davidson counties.

The "brown" phosphate is formed by the leaching of the Hermitage, Bigby and Catheys limestones of Trenton age and the Leipers limestone of Lorraine age. The original limestones contain a number of highly phosphatic bands, in which the phosphate of lime will run from 30 to 55 per cent, the rest being mainly calcium carbonate. When the latter is removed by rain water there is left a porous brown rock resembling sandstone, having from 70 to 82 per cent "bone phosphate," or lime phosphate. The rain water acts irregularly, as it gains access to the limestone through joints. Where the original rocks run high in phosphate the result is a firm "rock" phosphate. Where the original rock is low in phosphate, and that scattered, the result is a "sand," in which usually the proportion of sand and clay is high. Formerly only the "rock" was used; now the sand is washed, and when that is done thoroughly it is claimed to yield as high as 82 per cent of phosphate of lime.

The "brown" phosphate as mined occurs either as a "mantle" on benches or gentle slopes, or as a "collar" deposit following the outcrop of the limestone which yields it, according as the limestone outcrops on a gentle or a steep slope. The mantle deposits are rarely less than three feet thick, and often six feet, or even up to ten or twelve feet. The phosphate appears as a loosely coherent, porous, brown sandstone, lying in thin, horizontal plates in wavy lines, due to the irregular solution of the underlying limestone. The phosphate is mined without blasting.

The "blue and gray" phosphate is a bedded deposit at the base of the Chattanooga black shale. It has a thickness of from 4 feet down to nothing. It is variable in thickness and quality. To the southwest it runs into the Hardin sandstone. As a rule it does not run as high in phosphate as the "brown" rock, but for the manufacture of acid phosphate is superior to the latter, as it breaks down readily and does not require as much acid in its treatment, and dries out quickly after treatment. The rock is mined by stripping around the face of the hill until the overburden becomes too great, after which the bed is mined in the same manner as a thin coal bed, by running drifts and digging it out in rooms.

The "nodular" phosphate occurs as phosphatic balls, or nodules in the Maury green shale, and apparently of the same age. These nodules carry about 60 per cent of lime phosphate. Up to the present they have not been worked, as the difficulty of

getting out the nodules is too great as compared with the mining of other types of the rock.

The "white" phosphates are found in Decatur and Perry counties. They appear to be recrystalized calcium phosphate, or apatite. They occur in the surface mantle of debris, sometimes as a matrix in chert breccias; sometimes as a solid laminated layer. The phosphate appears to have resulted from the solution of phosphate rock at a higher horizon, and its redeposition, either in caves or otherwise.

It has been estimated that there remain six or seven thousand acres of "brown" phosphate rock, equivalent to 20,000,000 tons. Exploration is constantly increasing the amount, though much of that amount outside of the present Mt. Pleasant district is not of as high grade; nevertheless there seems quite a probability that large quantities of high-grade rock will still be found. When the time comes that it will pay to mine the unweathered phosphatic limestone vast quantities of such rock will be available. The "blue" rock does not appear to have as wide a geographic extent, but from its higher grade than the unweathered limestone it will be immediately available. It has been estimated that 100,000,000 tons remain; later exploration will probably increase that. The "nodular" phosphate, while not as rich as either of the two preceding, has a much wider extent. In the distant future it may prove a large source of supply. It is claimed that continued exploration has shown much larger areas of "white" phosphate in Decatur County than was formerly suspected.

*Pyrite.*—Pyrite, or as is often called, "fool's gold," is the golden yellow iron sulphate. It occurs in minute quantities in most of the rocks all over the State, especially in the Chattanooga black shale. There are few places where it exists in any quantity. It has been worked on Stoney Creek, in Carter County, 12 miles northeast of Elizabethton, and 1,000 tons have been reported as mined in one year. Large quantities have been found in Moore, Cheatham and Greene counties, as well as in association with the copper ores of Polk County. Now that the sulphur fumes from the reduction of the copper of Polk County are being utilized in the production of sulphuric acid, the demand for pyrite in this State is not so active.

*Salt.*—No salt is being mined in this State at present. Salt has been found in many of the counties of the State, notably: Anderson, White, Van Buren, Warren, Overton and Jackson.

Anderson and White counties have produced some salt, the latter having had an output for a time of 50 bushels a day.

*Sand and gravel.*—Gravel has always been used extensively for roads, and the use of cement has opened up a new demand for both sand and gravel. In 1908 Tennessee produced 565,325 cubic yards of sand and gravel, with a value of $290,050. Most of this sand and gravel is dredged from the bottom of the Mississippi, Tennessee and Cumberland rivers. The principal producing counties have been Shelby, Davidson, Knox, Hamilton, Rhea, Decatur, Benton, Roane, Johnson and Carter, with other counties producing small amounts. Glass sand has been noted under that head.

*Sandstone.*—Sandstone is but little used in Tennessee, partly because it is not so widespread as limestone, nor so readily available to the larger cities, and partly because of the difficulty of getting out the rock of uniform and pleasing color. Probably the rock most used is the Bon Air sandstone, which occurs along the west part of the Plateau. The buildings of the University of Sewanee are built of that rock. It has a mottled buff color and not unpleasant appearance. Near Pikeville is a stone that in places is a uniform pink. It has been used in buildings at Pikeville, in the State Penitentiary, and elsewhere. These stones are worked readily when first quarried, but in a few days the surface tends to harden until it is almost as hard as granite. The Clinch Mountain and Chilhowee sandstones are hard, and are worked with difficulty. Flagstones abound in the counties of the eastern Highland Rim. In West Tennessee the Lafayette is sometimes cemented into a sandstone that can be used for the foundations of buildings. As a whole the use of sandstone in the past has been mainly for rough masonry work, as for bridge abutments, curbing, flagstones for sidewalks, etc., and its use in this way has been in a large measure supplanted by cement. In 1908 only 830 tons were reported as quarried, with a value of $1,650.

*Shale.*—(See clay).

*Silica Rock.*—The use, when ground up and sized, of decayed chert, for polishing powder has often been suggested, and during the past year a company has been organized to prepare such rock, at Black Fox, in Bradley County. There are many places where the cherts of the Tullahoma and the Knox dolomites

weather on a large scale into a soft, porous rock that can usually be broken in the fingers. The development of the plant at Black Fox will be watched with interest.

*Silver.*—No silver ores have been found in Tennessee outside of the silver-bearing copper ores of the Ducktown region, in Polk County. There the metal is obtained as a by-product. In 1908 a total of 128,549 ounces were obtained, valued at $67,952. This was an increase of 43,017 ounces over the production in 1907. The gold and silver is recovered from only part of the ore, as the castings shipped abroad go unrefined.

Few metals have been hunted for more persistently than silver. Even in the few weeks since the establishment of the Survey many specimens have been brought or sent to the Survey, under the impression that they contained silver ore, in most cases accompanied by stories of Indians, marked trees, etc. Traces of silver have been found in most of the lead ores, but as yet not enough to pay for its refining. As regards the stories of Indians finding, or knowing the whereabouts of silver mines, a knowledge of the processes of metallurgy necessary to obtain the silver from its ore, and the fact that as a rule the ores of silver bear no resemblance to the metal silver, would at once stamp them as improbable, to say the least. Safford had this to say about such stories: "The numerous old Indian stories about silver mines, which are so common in East and Middle Tennessee, there being at least one, perhaps two, on the average, for every county, are entitled to no credit. To give specific account of them would require a volume, which, when written, would be worth practically nothing."

*Slate.*—No slate is at present produced in Tennessee. The metamorphosed slates of the extreme eastern counties, it is believed, form an inexhaustible supply. The slate is a pale green semi-talcose variety, very durable when free of pyrite, and splits readily into plates with smooth surfaces. The Wilhite slate has the necessary hardness, evenness and cleavage along the Little Pigeon River, and is well exposed over large areas, but not developed. Quarries have been opened in the Pigeon slate at many points, and slates and flags taken out for local use. In some cases the cleavage is across the bedding, and in others coincident with it. Slates are found in Cocke, Sevier, Blount, Monroe, McMinn and Polk counties.

*Sulphuric Acid.*—The copper ores of Ducktown are mainly

sulphides of iron and copper. In smelting those ores large quantities of sulphur-dioxide and trioxide are given off. Where allowed to escape into the air these fumes are very destructive to vegetation and crops. Recently both companies have constructed plants for the concentration of those gases into sulphuric acid. The sulphur-dioxide is first converted into trioxide and then it unites with water in the form of steam to form sulphuric acid. In 1908, with only one plant in operation, the value of sulphuric acid produced was $151,000.

*Zinc.*—Zinc mining in Tennessee is still in the development stage. In 1907 the output reached 251,198 pounds, valued at $14,821. Zinc ores are confined to the magnesian limestones, or dolomites of the State, notably the Knox dolomite of the great Valley of Tennessee. The Knox dolomite is a grayish white rock, non-crystalline, and more or less filled with chert nodules. In the Great Valley of Tennessee this rock is sharply folded and faulted in long lines lying northeast and southwest, and outcrops in belts between belts of other outcropping rocks. Most of the ore that has been developed occurs in three of these belts; the first belt crosses Claiborne and Union counties near New Prospect, and six miles southeast of Tazewell. At least two mines have been opened on this belt. The second belt follows the Southern Railway along the valley of the Holston River for forty miles. It is from 50 to 700 feet wide. The third belt lies further south and near the French Broad River.

In all cases the ores are originally sphalerite, or zinc blende, sometimes associated with galena, or pyrite, and occasionally with chalcopyrite. It occurs in coarse masses, or stringers disseminated in the magnesian limestone. It is usually found only below the level of ground water, except sparingly. When the limestone containing the disseminated blende weathers down by dissolving, there results a clay at the bottom of which the ore accumulates; but the ore also weathers into Smithsonite or Calomine, the former being zinc carbonate and the latter the hydrous zinc silicate, formed by the action of $CO_2$ released from the limestone. These ores will be found immediately overlying the limestones and under the clay. The name "Buck Fat" is given by the miners to a variable mixture of clay with calamine and smithsonite. It may be "hard," or "soft," and is usually too low in zinc to be mined under present conditions.

Ores of iron and manganese, as well as lead, are commonly associated with the zinc, as well as dolomite and calcite, fluorite, quartz and barite. The ores appear to be closely associated with the occurrence of breccia along fault zones or anticlines in the Knox dolomite. Thus at New Prospect, near Powell River, in Union County, the ore forms a narrow zone, striking north 50° east. Just south of the crest of Powell Mountain, six miles southeast of Tazewell, Claiborne County, the ores occur near a fault in the tilted rocks which form the lower part of the Knox dolomite. The second zone of deposits are also in brecciated rock following several small anticlines, as can be seen at Mossy Creek near Jefferson City, Jefferson County. Where calamine and smithsonite are found accumulated through weathering of the limestones, it is usually true that the weathering had descended by cracks or crevices so as to leave the surface when exposed very irregular, the unweathered portions projecting up into the clay.

Zinc mining has been carried on in a small way since 1883, when a mill was erected on Mossy Creek. Zinc is known to occur in a number of places in the Middle Basin of Tennessee. These have not yet been exploited, nor have they been developed.

## SURVEY BULLETINS.

The following bulletins have been issued by the Survey, and will be sent on request upon the receipt of postage as indicated. A list of the other parts of this bulletin are also given:

*Bulletin No.* 1.—Geological work in Tennessee. (Part A issued.)

A. The establishment, purpose, object and methods of State Geological Survey; by Geo. H. Ashley; 33 pages, issued July, 1910; postage, 2 cents.

*Bulletin No.* 2.—Preliminary papers on the Mineral Resources of Tennessee, by Geo. H. Ashley and others. (Part A issued.)

A. Outline introduction to the Mineral Resources of Tennessee, by Geo. H. Ashley, issued September 10, 1910; postage, 2 cents.
B. The coal fields of Tennessee, by Geo. H. Ashley (in preparation).
C. The iron ores of Tennessee, by R. P. Jarvis (in preparation).
D. The marble of East Tennessee, by C. H. Gordon (in preparation).
E. Oil Development in Tennessee, by M. J. Munn (in preparation).
F. The phosphate deposits of Tennessee, by Lucius P. Brown (in preparation).
G. The zinc deposits of Tennessee, by S. W. Osgood (in preparation).

*Bulletin No.* 3.—Drainage Reclamation in Tennessee; 74 pages. Issued July, 1910. Postage, 3 cents.

A. Drainage Problems in Tennessee, by Geoge H. Ashley; pp. 1-15; postage, 1 cent.
B. Drainage of Rivers in Gibson County, Tenn., by A. E. Morgan and S. M. McCrory; pp. 17-43; postage, 1 cent.
C. The Drainage Law of Tennessee; pp. 45-74; postage, 1 cent.

## NOTE

It was the original plan of the Survey to publish the material on *The Coal Fields of Tennessee,* as Bulletin 2-B; but from a change of plans, it was published as the leading articles in Volume III, No. 1 of *The Resources of Tennessee,* under the titles, *The General Features of the Tennessee Coal Field North of the Tennessee Central Railroad,* and *The Tennessee Coal Field South of the Tennessee Central Railroad.* This number of *The Resources of Tennessee* is herewith inserted, in order to complete the publications as originally outlined.

Volume III Number I

JANUARY, 1913

# THE RESOURCES OF TENNESSEE

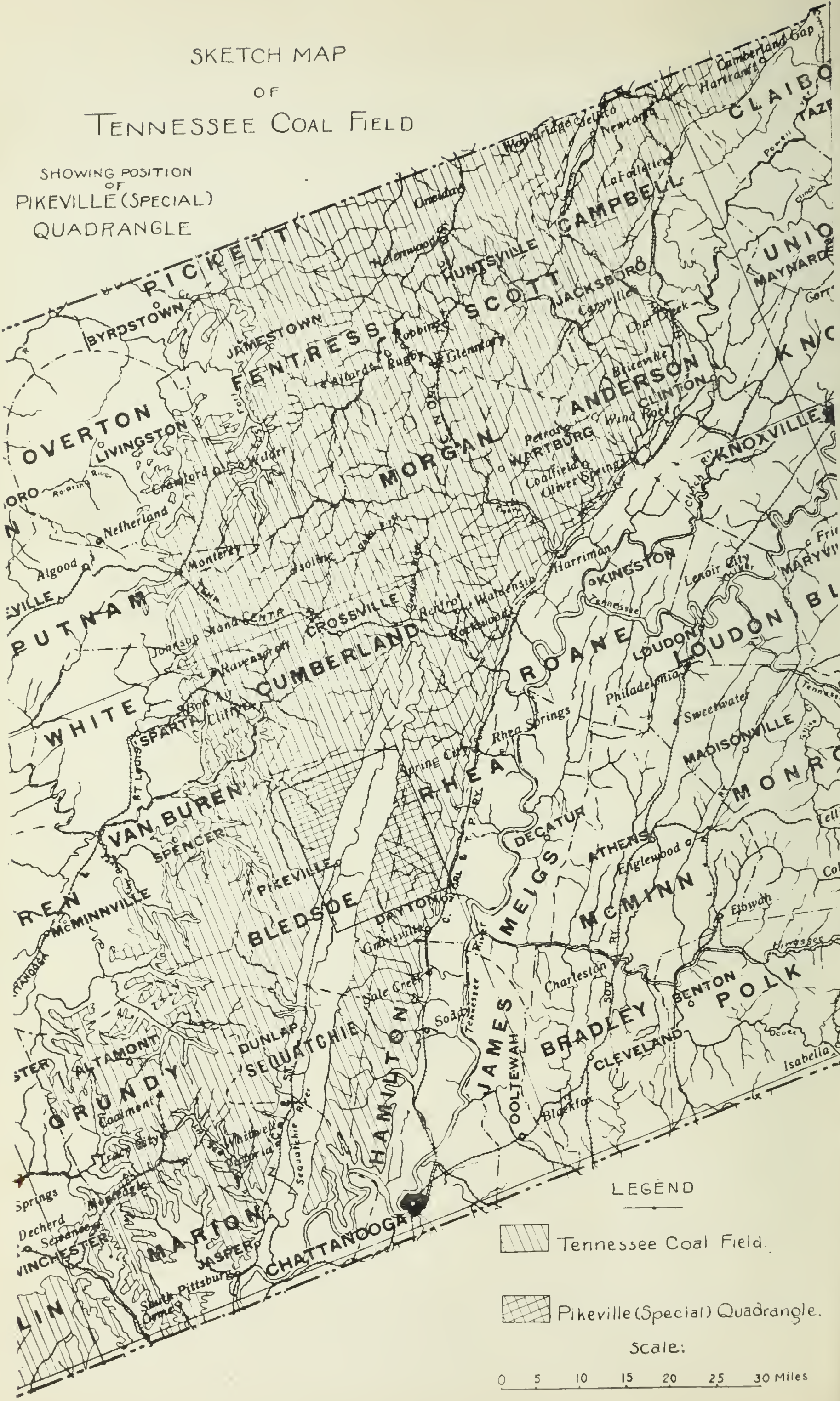
**Published by the State Geological Survey**



## CONTENTS

SKETCH MAP
OF
TENNESSEE COAL FIELD

SHOWING POSITION OF PIKEVILLE (SPECIAL) QUADRANGLE



# The Resources of Tennessee Will Hereafter Appear Quarterly

The *Resources of Tennessee,* which, for eighteen months has been issued as a monthly bulletin of the Tennessee Geological Survey, becomes a quarterly with this issue. As a monthly, the bulletin has brought many expressions of appreciation from both within and without the State. It is hoped that the persons who have expressed such approval and others who have approved the publication but have not given the approval expression, will not interpret this change as an indication of relaxed energy on the part of the Geological Survey. Rather it means that more energy will be expended upon other things than would be possible were the publication continued as a monthly. There are loud demands for bulletins on coal, phosphate, iron, clay, slate, soil, marble, bauxite, forestry, building stone, mineral waters, land reclamation, and other things. Securing the data for these bulletins will require much time and labor, and will tax the energies of the Survey to their utmost.

Through the medium of the quarterly we hope to supply information that the Survey has gathered and has not been worked over for a finished report, but which is demanded by the public. Of such nature is the information in the two papers on coal, published in this issue. Also, we hope by means of the quarterly to supply, as was done with the monthly, information on matters of importance, yet not requiring the space and expense necessary for a bulletin. We hope also by this means, occasionally to give the public the benefit of talks or lectures which seem to be of general value, and which relate to the work of the department, but which can not find their way to the people through the public press.

In this connection, it might be well to state that while it will be our effort to make the articles scientific, it will be the policy to eliminate all technical expressions possible. These will be left for the more comprehensive bulletins, to which the papers of the quarterly, as a rule, will be only preliminary. We feel sure that the geologists among our readers will see the place that the magazine is trying to fill, and excuse the want of completeness and scientific tone that will characterize it.

# The General Features of the Tennessee Coal Field North of the Tennessee Central Railroad

By L. C. Glenn.

*Purpose and basis.*—The purpose of the following preliminary report is to give a brief statement of the general facts now known as to that part of the coal area of the State, which lies north of the Tennessee Central Railroad. The report is based on a personal reconnaissance of the area made in 1911 and 1912, and is intended to give as much general information as is now possible in reply to the many inquiries received by the Survey as to the coals of this region. Necessarily, details are largely omitted and correlations of coals from area to area are touched upon lightly, since such work to be of certainty and value, can only be done in a region like this by careful detailed work. It is hoped that this reconnaissance may be followed by detailed studies of at least the more important parts of the region and that the results of these studies may be published in full detail.

*Divisions.*—The area to be considered may conveniently be divided into an eastern and a western part by a line approximately coinciding with the Queen and Crescent railroad from Harriman northward to the Kentucky line. These two parts stand in contrast to each other in their topography and geology, and in their economic importance and industrial development, as will be shown in describing each area. When the entire coal-bearing area of the State is considered, the above divisions form the northwestern and northeastern parts, and may be so designated.

## THE NORTHWESTERN COAL AREA.

This area lies, as has been said, north of the Tennessee Central and west of the Queen and Crescent railroads, and embraces parts of Pickett, Overton, Fentress, Putnam, Cumberland, Morgan and Scott counties.

Topographically, it is a broad plateau, with an average elevation of 1,200 to 2,000 feet. Its surface is level or gently rolling except along the larger streams, which flow in deep and narrow gorges, whose sides are formed in large part by cliffs of sandstone or conglomerate that in many places are 100 to 200 feet or more in height. These gorges may cut down entirely through the coal-bearing rocks and reveal the shales and limestones beneath, as for example, the gorge of Obey's River and of its

principal tributaries. The western edge of the coal field is an escarpment of irregular outline that overlooks the Highland Rim some 400 to 600 feet beneath it.

The rocks of the northwestern area are mainly confined to the lowest or conglomerate division of the coal measures, though toward the eastern part of the area these rocks are overlaid by a thin covering of higher coal measure rocks that are usually cut through along the streams, revealing the lower rocks beneath.

These lower rocks consist of conglomerates, sandstones and shales in very varying thickness and proportion. In fact the great characteristic of these rocks is their variability. At Monterey there are two beds of conglomerate, but the lower one quickly changes to shale and disappears to the northward. Farther east there are several. To the northeast in Fentress and in Pickett counties there may be either one or several beds of conglomerate. This conglomerate may contain abundant well rounded pebbles or may rapidly change laterally or vertically into a sandstone which is often of pinkish color. It is soft and easily disintergrated, and gives rise to the sandy surface which characterizes nearly all of the plateau. The shales also vary in short distances from a few feet to a score or more in thickness, and the coals likewise partake of this variability as will be noted presently. The thickness of this conglomerate, or Lee formation, is 250 to 350 feet about Monterey, but eastward and northeastward it thickens until it becomes 500 or 600 feet thick near Rugby and in northwestern Scott County.

The structure is simple. The rocks lie measurably flat over large areas, though they have a gentle inclination to the eastward and disappear by passing beneath the higher rocks that make the surface of the area east of the Queen and Crescent Railroad. A slight anticlinal fold extends into the area from the southwest at Crossville, but soon flattens out and disappears. Eastward at Crab Orchard there is an anticlinal fold of greater magnitude and of more economic importance.

The economic significance of the structure and topography are at once apparent. The coals outcrop only along the western edge of the plateau and in the sides of the deeper gorges cut by the streams that drain the western side of the plateau. Back from this eroded edge of the escarpment and from the stream gorges, they are entirely concealed by the rocks that form the surface of the plateau, and can only be reached by drilling. Prospecting and development where there are outcrops above drainage will be by simple and inexpensive drifting, but back on the plateau prospecting can only be done by drilling, and development must be by shafts, the depth of which will vary from 150 to 400 or 500 feet, according to location, the greatest depth being where the conglomerate is thickest in

eastern Pickett and Fentress, northern Morgan and western Scott counties. There the thickness of the conglomerate ranges from 500 to 600 or possibly 700 feet.

At Crab Orchard the anticinal folding has exposed the entire thickness of these lower coal measure rocks, but the coals are so badly disturbed by the crushing and faulting incident to their upturning that all attempts to mine them along their outcrop there, have so far failed. Away from their upturned outcrops they rapidly flatten out, and in a short distance, it would be entirely possible to reach them by shaft at a depth of one to three or four hundred feet, and the day is probablv not far distant when this will be done.

Another result of the folding at Crab Orchard is that on the flank of the fold on the eastern side of the mountain a coal in the shales above the top of the conglomerate, and generally regarded as the equivalent of the Sewanee coal, has been crumpled and squeezed until it shows at Fall Creek and elsewhere near there a usual thickness of six to ten feet, and in places is 20, 30 or even, it is reported, 40 feet thick. This abnormal thickness is of course compensated for by a corresponding thinning elsewhere in the immediate vicinity. This thinning is usually at a point *higher* or *lower* on the flank of the anticline and not along on the same level, though pinching out at the same level may occur at infrequent intervals.

COALS.

The coals of the northwestern area are mined in comparatively few places, and there are very few country banks or natural exposures. In much of the region the coals are entirely below drainage over large areas, and are totally inaccessible except by drilling, and so far very little drilling has been done. Our knowledge of the coals of this section is therefore limited and may or may not approximate the conditions in the large areas where they are yet unexplored.

The characteristic of these conglomerate coals is their variability. Their thickness is rarely the same over any considerable area. In one mine it varies often materially from room to room, and it is not certain that any one bed is continuous for more than a few or a few score miles. It seems certain that the coals of the conglomerate were deposited in local basins and that while neighboring basins in some cases were contemporaneous in others they probably differed somewhat in age. This greatly complicates the problem of tracing and correlating the coals of the conglomerate.

The lowest coals rest in places almost on the Mississippian limestone, while in other places they are 25, 50 or more feet above the limestone. A

mile south of Cook Place, the old Murdock opening shows a hard, clean splint coal that varies from 18 to 20 inches in thickness in a drift 125 feet in length. The roof varies from a good sandy shale to a weak slickensided clay. At an opening in this same hollow and probably only a few yards away, but now covered up, Safford reported this coal to be four feet thick. It seems to be of excellent quality, and would be quite valuable if on investigation it proved to average as much as three or three and a half feet over an area large enough to mine. Practically no prospecting has been done in the vicinity, and its extent and average thickness are unknown. It is about 55 feet above the limestone.

At Wilder, some five or six miles to the southeast, two thin rashy coals 10 to 12 feet apart occur at about the horizon of the Murdock coal some 75 or 80 feet above the limestone. Sixty-five feet higher the Wilder coal occurs. It is actively mined at Wilder, where it averages three and a half to four and a half feet in thickness, though it occasionally runs higher or lower than these measurements. It has no parting, but separates naturally into an upper, middle and lower bench, the lower being the highest grade, and the middle carrying some sulphur in balls or thin streaks. A mile and a half away the Overton Coal and Coke Company mine the same coal. It varies there from four and a half to six feet in thickness, with an average of about five feet, and is without partings. The same coal is mined at Crawford, where it averages three to three and a half feet in thickness, but varies considerably from this by thickening in sags in the floor and thinning in crossing intervening ridges. These sags run as a series of parallel troughs with a general northeast-southwest direction, and vary in width from a few to 1,200 feet each. On the ridge between adjacent troughs the coal may thin to 15 inches for a few feet or yards. The roof and floor are generally good.

Six miles south of Crawford a coal is mined at Obey City that is probably the same as the Wilder coal. It is in about the same stratigraphic position, and is similar in general character, though it probably carries somewhat more sulphur. It averages 34 to 40 inches in thickness and does not vary greatly from these limits.

North of Wilder a coal is known in several places on the tributaries of the East Fork of Obey River that is believed to be the Wilder coal, and it may be the same as the coal seen by the writer in Buffalo Cove at two places and measuring 54 and 56 inches respectively. The doubt in correlation arises from the fact that this coal is very close above the limestone while the coal at Wilder is 130 to 150 feet above the limestone. The two coals may nevertheless prove the same, the discrepancy in the distance down to the limestone being due to irregularities in the surface on which the coal measures began to be deposited.

Farther north in Poplar Cove a coal averaging three to three and a half feet, and worked for use in Jamestown, occupies about the horizon of the Buffalo Cove coal while farther northwest some six or eight miles a coal was formerly mined extensively for local use at several places on the ridge on either side of Crickett Creek. The workings were all fallen in when visited, but it was reported to be four and a half or five feet in thickness, and on the Smith place west of the creek this thickness must have been substantially correct. The quality seems to have been good, and it was free from partings, and seems to have a good roof.

East and northeast of Buffalo Cove, a number of drill holes have been put down. The earlier of these were with a churn drill, while the later were by core drill. They are grouped mainly within a radius of four or five miles of Allardt, though there is another small group on Clear Fork some eight or ten miles to the southeast. The writer has the logs of only a few of these wells. Of some of the others he has merely a statement of the thickness of the coal without exact information as to its depth, or as to the elevation of the well mouths. It is accordingly difficult to make as exact statement as is desirable as to the coals of the region. Coal is apparently thin or absent in churn holes, 1 and 3, in and three-fourths of a mile west of Allardt respectively, and in 4, some three miles northwest, and 5, about the same distance southwest of Allardt. In diamond drill hole D very near hole 5, the coal is three feet thick; in F two miles south of Allardt it is five and a half feet thick; in E near the mouth of Barn Creek four miles southeast of Allardt it is five feet thick; while other churn and core records at five points from one to three miles east of Allardt show the coal to be three, four and a half, five and five and a half feet respectively.

Three churn holes on Clear Fork some eight miles southeast of Allardt show four and a half feet of coal each.

From what can be gathered as to elevation it seems very probable that these records are all of the same coal, and that this coal is certainly the same as the Buffalo Cove coal, and probably identical with the Wilder coal. This coal shows an average of about four feet with a few places where it is thin or absent. From the wide distribution of the holes, it seems that there is a large body of coal three to five and a half feet thick in that region, that may be reached from the plateau level at a depth of 250 feet near the Buffalo Cove edge of the plateau or of 350 feet some six or eight miles to the east, or may be reached in the valleys of Crooked Creek and other streams at 150 feet or less, dependent on location.

To the north and northeast of Allardt and Jamestown the plateau level is not cut deeply enough by streams to reveal this coal until the Stearns mines in Kentucky, some 25 miles away are reached. There several coals

quite regularly four to five feet in thickness and of excellent quality, are mined. Two of these coals are only a few feet apart and very close above the limestone, the other known as the Barthell coal is some 40 to 60 feet higher. This latter coal may represent the Allardt coal, and if so, it would seem probable that the drill would show the Pickett and Fentress county region between these places to contain the same coal.

The logs of the Forest Oil Company's wells near Rugby show little or no coal in that region, and near Bledsoe's Stand, churn drill holes sunk some twenty or thirty years ago report no coal.

At Isoline there is a coal locally thick enough to be of commercial importance, that seems to lie at a higher horizon than the coals that have been described. It is only a few feet beneath the 60- to 100-foot bed of soft conglomerate that makes the plateau surface over large areas there and elsewhere. The coal lies in a trough 600 to 1,200 feet wide and is known to extend westward for two and a half miles, where it is five feet thick. What its farther extension is in that direction is not known. It runs from two and a half to five feet in thickness, and showed the following section:

| Shale roof | Inches |
|---|---|
| Coal | $2\frac{1}{2}$ |
| Bone | $2\frac{1}{2}$ |
| Coal | 2 |
| Bone | $2\frac{1}{2}$ |
| Coal, bituminous | 37 |
| Coal, cannel | 3 |
| Under clay, soft | 12 |

The coal is bright, fairly hard, lumps well and seemed free from sulphur balls and streaks.

No coals are opened or mined in the northern part of Cumberland County, except at Isoline. In the northeastern part of the county on Obed River at the mouth of Elmore Creek, an oil well recently drilled reports a coal over five and a half feet thick at a depth of 134 feet. This may be about the horizon of the Wilder and Crawford coal.

Just west of Crab Orchard Station, on the Tennessee Central, and again in Crab Orchard Mountain just east of the station, the conglomerate is upturned and its entire thickness exposed to view. Attempts have been made in both places to mine the coal exposed in it, but it was found too badly crushed and disturbed to make the venture a success.

Just above the conglomerate on the east side of Crab Orchard Mountain, at Fall, Millstone and Mammy's creeks, the Rockwood coal has been mined where it has been thickened up to 10, 20 or exceptionally 40 feet in lenticular pockets. The pockety nature of the coal has made its

mining very uncertain. The first of the above mines was being robbed preparatory to abandonment, the second was in litigation and closed, and the third had been abandoned when visited. It seems very probable that a little farther east from these mines there are a good number of square miles of territory in the middle of the broad flat-bottomed syncline between the Crab Orchard and the Cumberland mountains where this Rockwood coal will be found by drilling to be of good thickness and free from disturbance. So far as is known this region has not been explored with the drill. The Rockwood mines, however, have been operating for years on the eastern margin of the same coal and have workings that are now some two miles back from the mine mouth. The coal is about four feet in thickness and is coked and used at Rockwood in making iron. There is undoubtedly a large area in this section where careful prospecting would reveal coal thick enough and regular enough in its thickness to make it commercially practicable to mine it on as large a scale as might be desired.

The quality of the conglomerate coals would not be as high as the Coal Creek or some of the other coals of the northeastern section. This would not make much difference from a commercial standpoint, however, since these northwestern coals would not naturally find their market in the territory of the coals on the east of them but would be shipped westward into middle and western Tennessee and Kentucky, where they would compare favorably in quality with the coals from western Kentucky with which they would come into competition, and ought to be able easily to hold their own in competition with any of these latter coals.

Before they can be developed to any great extent it will be necessary to construct railways into the region. Much of it is 40 or 50 miles from transportation at present, and must remain undeveloped as long as the present lack of transportation continues.

It is true that in early days some coal in Fentress and Pickett counties was floated on barges down the Obey and Cumberland rivers to Nashville, but the price of coal in Nashville today is only a half to a third of what it then was and rafting coal is no longer practicable. Railroad building on the plateau would be easy and inexpensive, and almost any point could be reached without difficulty.

The conglomerate coals vary enough in thickness and are locally absent over small areas often enough to make it necessary to prospect any given property very thoroughly with a diamond drill before making purchase or attempting development. It seems from all of the evidence available, that the coals are more irregular and pockety in the region about Monterey, where an attempt to mine them failed because of the very pock-

ety character of the seam, and to the east and southeast, and that they become more persistent to the northeast and will probably be found, when prospected, in northern Fentress and middle and eastern Pickett counties to be more nearly like the Stearns coals in their thickness, regularity, and quality. By observing merely such precautions as would be obviously desirable in undertaking any plan for mining development anywhere, there is no reason why this territory may not be developed so as to yield as large a tonnage as may be desired.

Above the conglomerate the only coals of value in this northwestern section would seem to be the ones in its southeastern and northeastern corners. In the synclinal basin between the Crab Orchard anticline and the Cumberland escarpment, the occurrence of the Rockwood coal has been mentioned. It probably extends northeastward into the basins of Crab Orchard and Clifty creeks, but has received no development and probably has not even been prospected.

The rocks of this northwestern area dip gently eastward, and near the eastern edge of the area pass beneath the shales and sandstones that make the surface rocks of the northeastern distinct. At a number of places these higher rocks extend westward across the Queen and Crescent Railroad, especially from Sunbright northward to the Kentucky line. From near Oneida northward these higher rocks west of the railroad contain a coal that is mined at Bear Creek and is also mined at a number of places east of the railroad, as for instance at Glen Mary, Robbins, Almy, LeMoyne and elsewhere. At Bear Creek, the Virginia Mining Company's opening showed the following section at the head of the main entry and of the first and third right entries:

| Shale roof | Main Inches | 1st right Inches | 3d right Inches |
|---|---|---|---|
| Coal | 7 | 8½ | 7 |
| Splinty bone | 1 | ½ | 1 |
| Coal | 6½ | 6 | 6½ |
| Bone | 5 | 10 | 5½ |
| Coal | 20 | 18 | 19 |

This Bear Creek coal traces southwestward to Paint Rock at Almy and eastward to the LeMoyne mine on Gum Fork of Jellico Creek and farther tracing eastward makes it very probably the same as the Dixie coal at Newcomb and Jellico.

In summary it may be said of this northwestern coal field that it is very imperfectly known, largely because of the fact that except along its eroded western edge its coals generally lie several hundred feet beneath the plateau surface and are more expensive to prospect than where they crop at the surface. The conglomerate coals so far developed are rela-

tively high in ash and sulphur and are not coked, but are used exclusively as steam and domestic coals. They are marketed along the line of the Tennessee Central Railroad, a large part going to Nashville, and some is shipped through Nashville to points on other railways in competition with coal from West Kentucky. Little or none goes east beyond the end of the Tennessee Central since it then comes into competition with the near-by coals on the Southern and Louisville and Nashville railroads in the northeastern section of the field next to be described.

The Bear Creek coal finds its market on the Queen and Crescent road either for use by that road or for steam and domestic use northward in Kentucky or southward toward Chattanooga. Under certain market conditions, especially when strikes prevail in the West Virginia or the Illinois-Indiana region, this coal finds a market north of the Ohio River.

### THE NORTHEASTERN COAL FIELD.

This field embraces the coal-bearing area of Tennessee lying east of the Queen and Crescent Railway. It is roughly triangular and is bounded on the north by Kentucky, on the west by the railway just mentioned and on the southeast by the somewhat irregular but sharply defined line made by the Cumberland Mountain escarpment extending from Harriman to Cumberland Gap. It is the most important coal-producing area in the State.

Topographically it stands in sharp contrast to the northwestern region just described. Instead of being a plateau with a broadly flat or rolling surface beneath which narrow stream gorges here and there are cut, it is a maze of sharp crested ridges winding and branching in the most intricate fashion and separated from each other by deep and usually narrow V-shaped valleys, cut by the many-branching streams of the region. Many of the ridge crests rise to 3,000 and some even to 3,500 feet in height. In most places the ridge crests are sharply rounded, and some of these have good soils and are cleared, while in other places the crests are cliff-capped and wild. The sides are generally very steep except where some heavy sandstone here or there stands out in a line, it may be, of bold cliffs and holds just above it a gently sloping bench that contours the mountains possibly for miles. These benches are cleared and farmed in many places, but the steep slopes are usually heavily wooded. Roads are confined mostly to the stream valleys. Few of them cross the ridges, and many a mountaineer's cabin, perched high on a bench or on some ridge crest, may be reached only by a narrow, steep bridle trail.

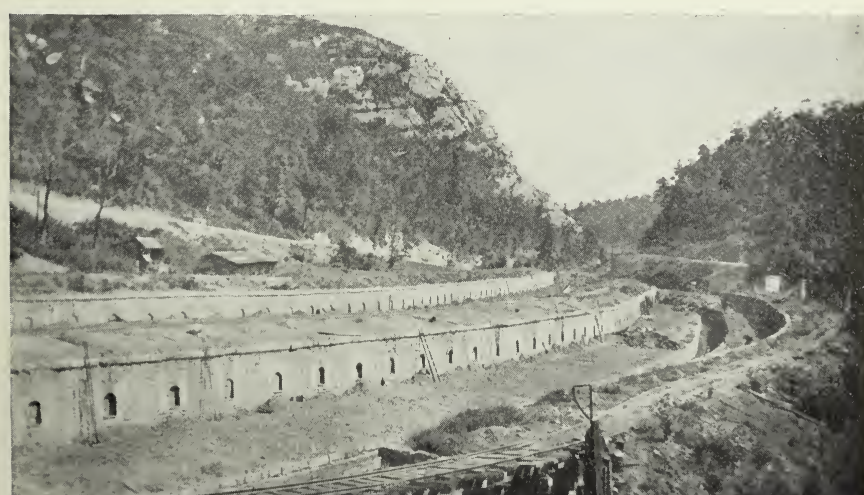
The deep dissection of the rocks of this northeastern region has removed much of the coal it once contained, since many of the thickest

coals are found on the middle or upper slopes of the ridges where they are comparatively narrow, and where the area that has béen removed by erosion is a number of times greater than that left in the ridges that remain.

While there has been such economic loss from erosion there has also been much enonomic gain since the deep dissection has laid bare some low-lying coals of great extent and value, as for instance the Coal Creek and Jellico coals, and at the same time has rendered the coals of the entire region much more easily prospected than are the coals of the plateau region.

Where the coals crop from the mountain side as those in this region do over most of their extent, it is so easy to open them by drift that when a coal goes under drainage level no effort is made to reach it by shaft. In many places a shaft mine would not be more expensive to open, operate and maintain, down say to the Coal Creek coal after it has gone under drainage level, than are some of the long, steep inclines used to reach the coals high on the mountain sides where the area of coal is probably small and the life of the mine correspondingly short as compared with a shaft mine, where the entire area about the mine contains coal. There are no shaft mines in the district, the nearest approach to such being the slopes by which the Rex coal is reached at LaFollette.

The geology also of this northeastern division is in direct contrast to the northwestern. Instead of one formation a few hundred feet thick in which sandstone and conglomerates predominate, we have here a number



Coke ovens, LaFollette, Tenn.

of different formations aggregating 2,000 to 3,000 feet in thickness in which shales predominate. Instead of having one, two or three coals as in the conglomerate we have here a dozen or two of coals, quite a number of which are at one place or another of commercial thickness and value. In addition to these coals above the conglomerate and accessible over most of this region above drainage, the conglomerate itself also extends under all of this region and doubtless contains coals of value that will some day be reached by shaft, as the top of the conglomerate lies only a few to a few hundred feet beneath drainage level in much of this northeastern section.

The rocks above the conglomerate have been divided by the U. S. Geological Survey into a number of formations, but in the present brief description it will not be necessary to describe these formations or give their areal extent. The folios in which they are described and mapped may either be obtained in Washington or are accessible in many libraries.

In structure this division is not quite so simple as the northwestern one. Its eastern and southeastern edge is delimited by the Cumberland escarpment where the coal-bearing rocks rise rapidly into the air to the southeast along a line usually of faulting with an overthrust from the northwest. This line extends from Cumberland Gap almost straight southwestward to near Careyville and there curves to the southeast to Coal Creek beyond which it soon resumes its usual southwest course and under the name of Walden Ridge extends to Harriman and beyond.

Ten miles northwest of and parallel to the Cumberland Mountains there is the Pine Mountain fault. It extends from near Jellico southwest to Pioneer, where it turns sharply to the southeast and becomes a cross fault that joins the Cumberland Mountain fault near Careyville. The overthrust here is from the northeast and the ridge made by the conglomerate is known as Fork Mountain.

This Pine Mountain fault is overthrust from the east and the upturned conglomerate forms the crest of the long rugged Pine Mountain ridge, just as it does the parallel crest of the Cumberland to the southeast. The basin enclosed between the Cumberland, the Fork and the Pine mountains is thus separated structurally from the rest of this northeastern field. It is drained almost entirely by Clear Creek, and may be called the Clear Creek basin. In this Clear Creek basin the steep inward dips on either side quickly die away, especially on the Cumberland Mountain side, and in a few hundred feet the rocks become flat. Such abrupt flattening is indeed, characteristic of both the Cumberland and Walden Ridge, at least as far south as Rockwood.

The remainder of the northeastern coal field is a very broad shallow basin with very gentle dips. Much the larger part is drained by New

River, which flows approximately along the axis of this basin. It is probable that the syncline has a northern branch that parallels Pine Mountain and is occupied by Jellico Creek. Dips in all cases are gentle except for local minor folding such as may be seen on Brimstone Creek near the mouth of Hutson branch.

The Clear Creek basin between the Pine and Cumberland mountains may be considered as a unit. It is crossed diagonally by the Louisville and Nashville Railroad, and a branch of the Southern extends up Clear Fork to the Kentucky line. Numerous mines are operated on these lines of road and the relation to each other of the coals now developed is reasonably clear.

The lowest coal mined in the basin is the Rex. It is about 300 feet above the Lee conglomerate and is doubtless equivalent to the Coal Creek coal which it resembles in various ways. It is mined at LaFollette. The roof is slate that where undisturbed may hold very well, but which falls readily when shot down along entries. About a foot from the top the coal generally has a parting that varies from 0 to 12 inches with an average of about two inches, while the coal beneath it averages two feet. This coal is low in ash and sulphur, and is coked for the furnace at LaFollette. Above it at LaFollette 513 feet is a coal locally known as the Kent. This coal was formerly worked immediately above Rex mine Number 2. The section varied much in different parts of the mine. The top coal varied from 5 to 25 inches, then came a dirt band from 1 to 18 inches beneath which the bottom coal varied from 18 to 26 inches. It was high in sulphur and ash. It seems very probable that it is the equivalent of the Jellico coal.

At the Gem mine some seven miles north of LaFollette on the ridge between the head of Lick and Rocky creeks a seam locally known as the Jordan, is worked. It is reported to be 1,200 feet above the Rex coal there, which was supposed to be reached in a bore hole at a depth of 620 feet. Two small coals regarded as the Kent, there split, are found 500 feet beneath the Jordan, which has an elevation above sea of 1987 feet at the mine mouth. It dips gently northwestward and varies but little from 48 inches of coal with a parting usually about a foot from the top that varies from one to six inches. This parting may be rash, or clay, and either free from or mixed with coal. The area, owing to the elevation, is limited, but two or three miles to the northeast it is mined at Cotula, where it has very similar section and thickness, except that the parting varies from zero to four inches, and part of the coal runs up to five feet or occasionally more in thickness.

In the section along the Louisville and Nashville Railroad from Cotula north to Chasca the lowest seam exposed is the Kent or Jellico. It is split

into two benches the lower of which has been mined at several places generally under the name of the Italy seam. It averages 34 inches and has a sandstone roof and hard shale floor that make working expensive. At Cotula, it is below railway grade, but near Chasca it begins to rise rapidly to the northwest under the influence of the Pine Mountain fault.

About 220 to 290 feet above the Kent or Italy seam along this section of Davis Creek is the Rich Mountain seam mined at Wynn, Remy, Rich Mountain, Cupp, Kimberley and Chasca. It has an average thickness that varies in different mines from 30 to 44 inches and may or may not have a thin clay parting in the middle or lower part and generally has several inches of rash beneath it.

Some 90 to 125 feet above the Rich Mountain coal on Davis Creek is the Log Mountain seam. This seam is mined only at Jackson and Westbourne, where it averages about 44 inches and is solid. Elsewhere it seems to be split or thin in this section in the few places where search has been made for it. In the western part of each of the above mines the upper 10 inches is cannel. In the eastern workings this cannel disappears.

This Log Mountain or Westbourne coal is believed to be the same as the Dean, the Poplar Lick, and the Bryson Mountain coal. The area above this horizon in the ridges in the Clear Creek basin is in the aggregate large and further prospecting will doubtless disclose other areas where it is of workable thickness as it is a coal of widespread occurrence both in Kentucky and in Tennessee.

About 150 feet above the Log Mountain coal is the Jordan which, as has been seen, is mined at the Gem mine at Peabody, and at the Southern Coal and Coke Company's mine at Cotula. The writer is not certain as to the correlation of the Jordan coal. It has been correlated by some with the coal known as the Dean or Poplar Lick. About 100 or 125 feet above the Poplar Lick coal in the Middlesboro region is the Klondike or McGuire coal, which carries marine fossils. In the Coal Creek and New River region a coal known as the Big Mary is also characterized by the marine fossils it carries, and is associated with other coals above it, one of which is usually correlated with the Dean. It is probable that the marine fossils characterize the same coal, and if so the Dean could not be below it in one region and above it in another. This tangle of correlation can only be worked out by future detailed work.

At Morley, two mines work a coal that is locally called the Kramor seam. It is 32 to 35 inches thick, is about 250 feet above the top of the conglomerate and is probably to be correlated with the Rex seam of the LaFollette region.

On Clear Fork at Anthras and Clairfield several mines operate on a coal generally considered to be the Jellico. It varies much in thickness

in the mines and prospect openings that have been made. Where mined it averages from 42 to 52 inches and may be solid or may have a parting that varies up to 12 inches in thickness, but is frequently absent. In a prospect on Rock Creek, the thickness is reported as 68 inches. There is a large area to the south of Clear Fork in which this coal occurs, though its thickness there is not known.

Near the head of Clear Fork at Pruden and at Fonde a coal some five or six feet in thickness is extensively mined. It is usually split into three benches by two clay partings and in a portion of the area the upper parting is so thick that only the two lower benches of coal are mined while in other portions the upper parting is thin and the lower so thick that the middle and upper benches of the coal are alone removed.

In some places it splits into four or five benches of coal, but generally some two are large enough and near enough together to be worked. This coal is the same as the Mingo coal of Bennett Fork. Its relation to the coal mined at Clairfield and Anthras—and usually considered to be the Jellico—has not been ascertained by the writer. One report places it 435 feet above the Clairfield coal. The Mingo has often been correlated with the Jellico, but if it is 435 feet above the coal at Clairfield, it is evident that one or the other of these two correlations is badly wrong.

In the Clear Creek basin spur tracks from the Louisville and Nashville or the Southern might easily be extended up any one of the numerous tributary streams and thus develop much new territory now untouched.

The discussion of the remaining portion of this northeastern coal field can best be undertaken by districts, beginning at Jellico and going southward and westward around the margin of the basin. This description may be relatively brief since many of the largest mines are on one or the other of a very few seams, such as the Coal Creek and the Jellico.

At Jellico the lowest coal known locally is the Swamp Angel. It is found at or a short distance below, drainage level and is reported to be 32 to 34 inches in thickness. It is not mined. About 100 feet above it is another unmined coal known as the Dixie. It may be solid or split by a clay parting and is said to be 24 to 36 inches thick. Either this or the Swamp Angel is at about the horizon of the Coal Creek coal. This Dixie coal, when traced westward, correlates with the coal mined at the LeMoyne mine on Gum Fork of Jellico Creek. At LeMoyne there is a main bench of 30 to 33 inches above which there is a parting that is left as the roof. Above this parting, which varies from 8 to 36 inches, there are five inches of poor bony coal that is not mined. About 100 to 120 feet above the Dixie there is a thin coal near Newcomb, known as the Black Wax, and some 60 or 70 feet above it is the Blue Gem coal. This coal is always thin, but is of such excellent quality as a domestic fuel that a

thickness of 18 to 22 inches is mined in numerous places about Jellico. It is also mined at Elk Valley, where it varies from 16 to 24 inches.

About Jellico the Jellico coal is 90 to 110 feet above the Blue Gem. It varies greatly in thickness and in details of section within short distances. In one mine it varies from two to six feet. It may be solid, but more frequently has one or two partings, which vary in thickness, and in position, but which rarely prevent the coal from being mined. It is mined at Jellico, Newcomb and Elk Valley.

Four hundred and forty feet by aneroid above the Jellico coal at Newcomb, there is an excellent cannel mined by the Zcheni Coal Company. It shows a top bench of 24 to 26 inches of cannel, one to two inches of parting and 8 to 11 inches of cannel, and is known to underlie a considerable area in thickness great enough to mine. Some other coals are known to occur above and below this cannel, but they have not been prospected sufficiently to determine their thickness or value.

At Pioneer, two coals were formerly mined that are known as the Upper and Lower Pioneer. These are relatively high in the stratigraphic section, but no attempt will here be made to correlate them with other coals. Neither is worked at present and but little information could be secured as to their thickness or character. They lie well below the tops of the ridges about Pioneer, and large areas to the northwest, west and south of Pioneer rise above their horizon. What their extent and thickness throughout this territory may be is not known.

Three miles south of Pioneer a spur track passes east through the gap in Fork Mountain and reaches the Rector mine, which was opened on what appears to be the Kent seam. When driven in about a thousand feet, the coal was cut off by a fault and the mine was abandoned. Some three miles east of there on the head of Ollice Creek, the same coal occurs. In each place it is four feet thick. This coal is also known at several points on Stinking Creek north of Walnut Mountain, so that it underlies much the larger part of the Clear Creek basin from Fork Mountain northeast to the Louisville and Nashville Railroad. We have already noted its development along that railroad, where it is usually known as the Italy coal, and its development also at Anthras and elsewhere on Clear Fork, where it is known as the Jellico.

By a little geological work at Rector at the proper time the continuation of the seam beyond the fault could have been located and the mine might have been saved to its owners.

At Turley, Block, Red Ash and Careyville, there are a number of mines that work one or the other of two coals, situated near the tops of the mountain ridges. The strata rise considerably to the southward so that each coal is carried higher in that direction. Their general elevation

where mined may, however, be taken as 2,300 to 2,750 feet above sea level. They are reached by inclines one to two miles long that have a vertical rise in that distance of 1,000 to 1,400 feet. The coal is lowered by gravity in monitor cars holding 10 to 12 tons each. The ridges at the horizon of these coals are relatively narrow so that individual bodies of coal readily worked from one opening average 400 to 800 acres.

The higher of the two high ridge coals mined at the above places is locally known as the Rock Spring coal. It is mined at Turley and at Block, and is known to occur for some miles along the ridges and high spurs on the north side of the Montgomery Fork basin. By its rise to the southward it is carried up so near the tops of the ridges in that direction that it is doubtful if there are any considerable areas of it left there. Its exact extent, however, like that, indeed, of all of the other coals of the region is not known and can only be ascertained by detailed work.

A section of this is as follows:

| | Inches |
|---|---|
| Coal | 19 |
| Bone | 4 |
| Coal | 33 |
| Clay | 3 |
| Coal | 13 |

In some places the bottom bench of coal is absent or is bone and rash, and the bone between the two upper benches in places disappears, leaving a solid bench of 40 to 42 inches. The coal is hard and carries some sulphur in the bench above the bone. This bone is inclined to stick to the coal when present. Mining is either by machine or by shooting on the solid.

At Block 325 feet by aneroid below the Rock Spring coal another coal occurs that averages three feet in thickness. It is known as the Red Ash, and is mined at Block and is generally believed to be the coal mined at Red Ash, Careyville and the Sun mine. At Red Ash this coal has a top bench of 38 inches, then, clay two inches and coal one and a half inches. At Careyville the coal is solid and averages 46 to 48 inches, and seems quite regular. At the Sun, it varies from three and a half to five feet in thickness, and on the right workings is solid, but on the left a soft clay appears slightly below the middle and had run up to eight inches when further work in that direction was stopped. It is not yet certain to the writer that these are all the same coal, though the Careyville and Red Ash mines are on the same seam.

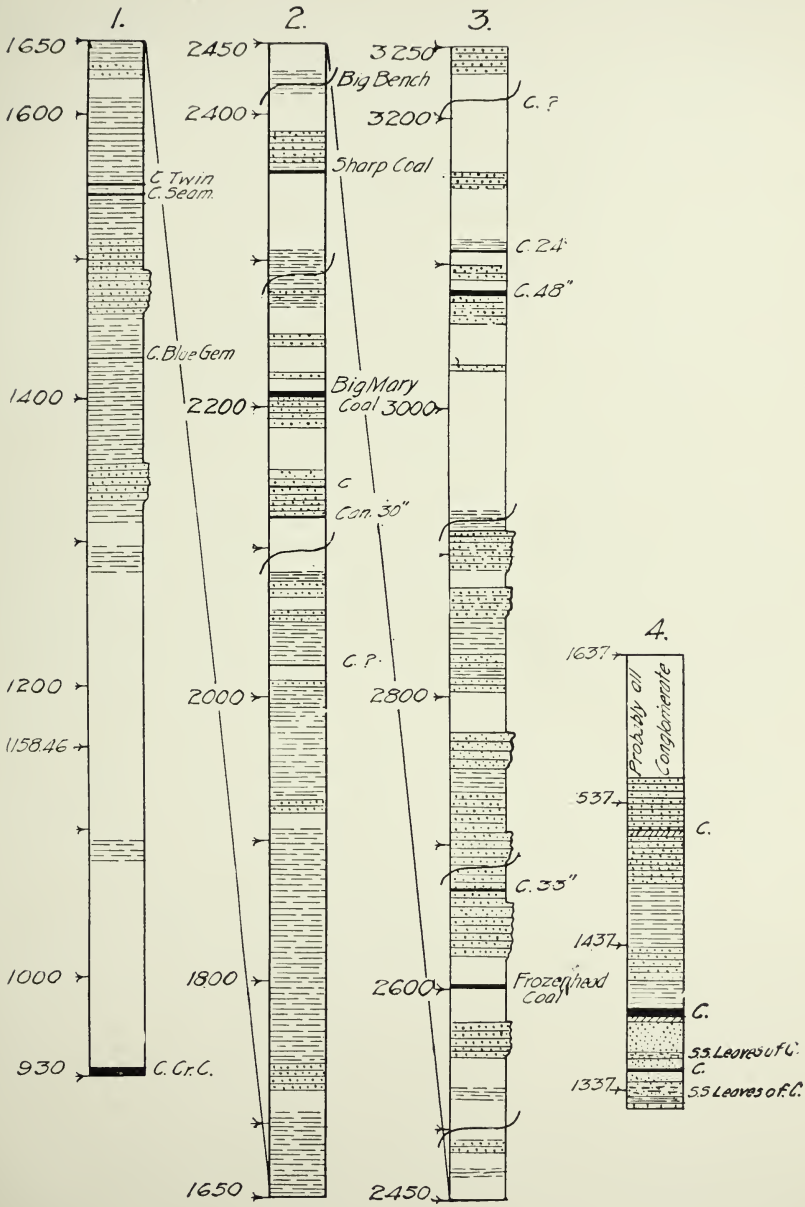
The next mining region south of Careyville is Coal Creek, with which Briceville is included. The Coal Creek seam has been mined here for years on an extensive scale. The coal crops close above drainage for

some 8 or 10 miles along Coal Creek and Valley Fork. It averages in the various mines 40 to 48 inches in thickness, with 42 inches as a general average, but varies greatly in detail in any one mine. Where of average thickness it perhaps more often has a knife edge to 4-inch parting than not. This parting is usually slightly below the middle. In some places the coal runs up to six feet locally and in a small mine just north of Briceville it is even thicker. The roof varies from a good sandy shale to a soft clay from place to place in the same mine, and when of clay requires much timbering and care to hold until worked. The top six to eight inches of the floor is a clay that softens when wet. The mines on this coal are usually dry and sprinkling is often necessary.

Near the crop this coal dips westward as much as 8 to 12 per cent. in places, but soon flattens out and over large areas has scarcely any dip. Some of the workings extend two miles into the mountain. Northward from Coal Creek its outcrop is soon concealed by the great Walden Ridge fault line except for a short distance near Careyville where it is mined by the Bear Creek Company. In the Briceville-Coal Creek region this is the only coal mined and until very recently no others had even been prospected to any extent.

Just recently some active prospecting has been done by Mr. L. J. A. Petrie on the mountain side west of the Black Diamond mine. Here he has faced a number of coals whose position and thickness are given on the long vertical section given herewith. These facings show that there are several promising coals well toward the top of the ridge, but still low enough to give a very considerable acreage. Similar work had been begun by Mr. E. F. Buffat on a spur of Cross Mountain west of Briceville, when this region was visited by the writer. It is evident that there are several promising coals in Cross Mountain some 1,200 to 1,600 feet above the valley floor to the east and some of them undoubtedly correspond to the coals mined some miles to the north from Careyville to Turley.

Southwestward from Coal Creek the next mining center is the Oliver Springs region. Oliver Springs bears much the same topographic and structural relation to the coal-bearing area that Coal Creek does. The Coal Creek seam is likewise the best known seam in the region. It is often called the Poplar Creek coal and outcrops at a number of places on Poplar Creek, Big and Little Cow creeks, and westward on the head of Little Emory River north of Coalfield. It has been mined at numerous places in this Oliver Springs district in the past and is now mined at Big Mountain and elsewhere on Indian Creek, and in the vicinity of Coalfield. It lies only a short distance above drainage, in most places, and has many of the same general characteristics that it has at Coal Creek. Its average thickness is about 48 inches and it may be with or without a




Sec. 1-2-3. Vertical section from the Black Diamond mine westward up Cross Mountain.

Sec. 4. Churn and diamond drill record D near Allardt.

parting and the roof may be either a shale or a soft clay. Beneath it there is always clay. This coal is not definitely known northward on the New River basin. It is probable that it is one of several small coals that rise above water level near the mouth of Bull Creek a few miles below Norma.

Some 1,300 to 1,400 feet above the Coal Creek coal there is a seam that is extensively mined at Windrock, where it is considered to be the Lower Dean. It averages 54 inches in thickness, but varies much in detail. In a part of the mine the coal is solid while in another part a thin band appears that thickens as shown by the drill, to 35 or 40 feet and then thins away again in no great distance to a few inches. Splits are of frequent occurrence in many of the coals of this northeastern region, and while rarely known to be anything like as large as the above one, they serve to puzzle the prospector and increase the difficulty and expense of operation.

This Windrock coal is very soft and friable and is sold almost exclu sively as a steam coal.

Northwest of Coalfield the Coal Creek coal soon goes under drainage and on the upper slopes of Little Brushy Mountain at an elevation of 1,700 feet, the State or Brushy Mountain seam some 600 feet above the Coal Creek seam, appears and is worked by the Little Brushy Coal Company. Its average thickness there is 34 inches, and it is without parting. Northward at Petros, it is mined by the Big Brushy Company and by the State.

It varies much in thickness, but averages some 40 to 44 inches. It may be free from partings or one or more may be present either of rash or of clay. These partings are frequently in lenses only two to five feet across, or they may be persistent for some distance. The roof is generally a good shale, the floor is a clay. This seam is driven through to daylight on the New River side, but it has not been prospected beyond a mile or two north of its crop. It is a soft coal, cokes well and goes as coke to the iron furnaces chiefly at Dayton and Chattanooga, or is sold to the steam trade.

Attempts were made a few years ago by the State to mine a seam some 750 feet above the State seam, generally known as the Frozenhead seam, and correlated by some with the Upper Pioneer. The coal thinned to some three feet or less when the mine had been driven in some 2,500 feet and the mine was abandoned. A 32-inch coal 130 feet below the Frozenhead was opened and driven some 30 feet. It is solid and apparently good and clean. A hundred feet lower is another coal once opened but reported as badly split.

In the New River basin very little prospecting has been done and almost no mining. On Straight Fork of Smoky Creek the Big Mary coal

was opened and mined for a short time by the Baker company. Where measured it has a main bench of 37½ inches above which were several thin alternations of coal, bone and partings. As usual it carries marine shells in the roof. The attempt to mine this coal was soon abandoned partly because of local freight rates and partly because of the unsatisfactory character of the seam. The Big Mary seam is everywhere very variable and unreliable, although it often presents locally a very attractive appearance. This coal has been faced on the head of Brimstone Creek of Smoky Creek where the only bench of consequence is a bottom one of 27½ inches. Two hundred and fifty feet higher another coal 50 to 52 inches and solid has been faced and 60 feet still higher there is a 38-inch solid facing. The 52-inch coal is a good-looking clean, hard coal.

On Round Knob some eight miles southwest of Norma, at an elevation of some 2,000 feet there is a solid 64-inch coal on the Tom Jones place. A five-inch band of splint coal separates the bottom 12 inches from the top 47 inches. The coal looks good and clean.

Just westward from Round Knob on Brimstone Creek 20 to 60 feet above water level, is a coal that has been faced at a number of places from below Hutson's branch up to Mill Creek, where it goes under drainage. It is about a thousand feet below the coal at the Jones place. It varies somewhat, but averages about 36 inches of solid, good-looking coal. Westward on Indian Fork at the Sam Walker opening it shows top and bottom benches of 20 and 38 inches of coal separated by 15 inches of clay. On the head of Aaron branch it has top coal 37 inches, bony shale four inches, coal 18 inches. Opposite the mouth of Pemberton branch, it is 42 inches and solid. At Robbins it shows 31 inches of solid coal.

This coal is widely developed in Brimstone Creek basin and crops on the mid-slopes or near the base of the hills. It is the same as the coal mined at Glen Mary, Helenwood, Almy, Bear Creek and LeMoyne, and mentioned on page 11. At and near Almy there are a number of mines working it. It averages there 24 to 30 inches, and at Glen Mary has about the same average. The roof there is usually good and the coal is clean. Most of it is used as steam coal.

The coals in the New River and upper Emory River basins are very imperfectly known and need extensive prospecting and much more study before any very broad statements may be made concerning them. Good coals undoubtedly exist in these basins, but before they can be developed, adequate transportation facilities must be provided and at reasonable rates, since competition is so keen today in the coal trade that a few cents difference in freight or other charges make the difference between success and failure.

Very much of the coal land in this northeastern field is owned by holding companies who lease it to operators at royalties that vary from 6 to 12½ cents per ton. The tendency in recent leasing has been toward the mean or minimum of the figures just given and the maximum royalty quoted above is regarded as high for present market conditions.

In marketing the output of this section, competition is more severe today than at any time in the past, since the development a few years ago of mines on the Louisville and Nashville and the Southern railways in the Clear Creek basin, added much to the local output, and at about the same time the opening of important new fields in southwest Virginia and the construction of new lines of road to deliver these latter coals to the mill section of the Carolinas and Georgia, further unsettled the coal trade and forced a readjustment in markets and rates that has not yet perhaps settled to equilibrium. Added to these conditions has been the fact that the State can produce coal materially cheaper than any private operator can, and so is in a position to quote prices when dull seasons come that are low enough to secure orders to keep her mines running and her convicts busy, but that are so low they would quickly force any private company into bankruptcy.

To what extent in point of fact the State of Tennessee avails itself of this peculiar advantage that it undoubtedly possesses, the writer does not know, but it is generally felt among private operators that they are subjected in this way by the State to such unfair competition that there is a strong sentiment already developed among them that the State should take her convicts from the mines and place them on the public roads.

In a few years when the present seam mined at Petros is exhausted it would be very pertinent to raise the question—if, indeed, it should not be done now—whether the State should not abandon the policy of mining coal, as a matter of simple justice and fairness to her citizens engaged in the same pursuit and use her convicts in such road building.

In a rapid reconnaissance such as the one on which this report is based, it has not been possible to see more than sample areas of the various undeveloped sections and time has in the same way been lacking for following out the many problems of distribution and correlation that the studies in any one locality suggested. In this brief article it has furthermore not been possible to give more than a general glimpse of the field. Some of the description has been generalized so much that the local operator with his probably detailed knowledge of his own locality may regard it with scant favor. The attempt here, however, has been throughout, not especially to give him more knowledge of his own region than he now possesses, though this is doubtless true in some instances, but rather to give to the man who knows nothing whatever of this section

of the State's coal area some general ideas of its coal content that it is hoped may be true so far as they go. It is hoped that detailed work may follow and that the enquiries of the man locally familiar with this or that section may be capable of satisfactory answer as a result of such work. Many courtesies and much information have been received during the work. It would be impossible to name all to whom the writer is thus indebted as the list would include every mining man from owner and manager on down, with whom the writer came in contact. He can not refrain, however, from expressing his great indebtedness to Mr. H. Murman, of Coal Creek, for much information with regard to the coals of that region with which his years of work have made him so familiar.

# The Tennessee Coal Field South of the Tennessee Central Railroad

By Wilbur A. Nelson.

## INTRODUCTION.

*Purpose and basis.*—The purpose of this report is to give in a very general way much of the information that has been collected by the Geological Survey on the southern Tennessee coal field. It is a preliminary report in the strictest sense of the word, and will later be followed by a much more detailed one. Very little attention is given to stratigraphy, as it takes much detailed work to correlate correctly the coals over a large area, and this has not as yet been satisfactorily done. It will be taken up in the subsequent paper.

The report is based on a personal investigation, made to conform with the objects of this paper. The field work was done at odd times during the years of 1911 and 1912, and in all not more than a month or two was spent. Naturally many points were not visited, but as a whole the entire area was well covered.

## LOCATION AND EXTENT.

*General character, extent and relation.*—This coal field is a part of the Great Appalachian field, which extends from northern Pennsylvania to central Alabama. In the northern part of the State are found the same beds as in Kentucky, and in the southern part the same beds as in Alabama. As this paper deals with the southern part of the field, the coals correspond more in general character to the Alabama coals than the Pocahontas coal of West Virginia or the Clearfield coal of Pennsylvania.

The coal field of Tennessee is the Cumberland Plateau which extends in a northeast and southwest direction across the State, forming the dividing line between Middle and East Tennessee. The field has an average width of from 35 to 50 miles. It covers practically all of Bledsoe, Cumberland, Marion, Morgan and Scott counties; the western part of Anderson, Campbell, Claiborne, Hamilton, Rhea and Roane; nearly all of Grundy, Fentress and Van Buren counties; and the eastern side of Coffee, Franklin, Overton, Putnam, Warren and White counties. For a description of the northern part of the Tennessee coal field see the companion

article on *The general features of the Tennessee coal field north of the Tennessee Central Railroad,* by L. C. Glenn.

*Area of field.*—In that part of the coal field south of the Tennessee Central Railroad, comprising 2,200 square miles, the area containing coal measures above the Sewanee conglomerate, comprises only 1,420 square miles, divided as follows: Walden Ridge 665 square miles; south of Van Buren County, 240 square miles; north of the Van Buren-Grundy and Van Buren-Bledsoe county line, 515 square miles. These figures show that in the southern counties much of the upper coal measures have been removed by erosion.

### TOPOGRAPHY AND DRAINAGE.

*Topography.*—The Cumberland Plateau, which contains the Tennessee coal field, is a broad upland, standing about 2,000 feet above sea level. As a rule the surface is nearly flat, or only slightly rolling. The streams flowing out to the east, west, and south have cut many deep ravines in this upland, but in proportion to the broad upland, they occupy only a small part of the area. The result of this condition, is that the coals have been brought to the surface at a large number of points, at the same time, they have been greatly protected, so that in many cases almost as large an area of the beds remain as though they were entirely below drainage. These conditions prevail in the northern part of the field. It may be easily seen that the sandstones are not responsible for the general flatness of the plateau, for the surface bevels a number of massive sandstones as well as the intermediate less resistent shales and shaly sandstone. This is well seen in Walden Ridge, where the sandstone that protects the eastern edge of the plateau is stratigraphically 500 to 700 feet lower than the same sandstone which protects the western edge overlooking the Sequatchie Valley.

On the eastern edge of the plateau, there is a fairly even escarpment with a precipitous drop of about 1,000 feet, and the streams that drain this area lie at the bottom of long narrow gorges. On the western edge there is a similar drop, but the edge of the escarpment is not regular. It ramifies back and forth, forming numerous headlands separated by deep dendritic like coves. The ends of these headlands have in a few cases been cut off and now stand out as isolated outliers. The Sequatchie Valley extending nearly half way across the State in a general direction of north 30 degrees east, bisects the plateau in the southern half of Tennessee. This long narrow anticlinal valley ending in the Crab Orchard Mountains, which rise up nearly 2,000 feet above the valley, has its sides formed by the steeply upturned strata of the coal measures, which quickly flatten out in either direction from the valley escarpment. The average

height of the plateau along this valley is about 1,000 feet, but on the eastern side going north, one sees an imposing array of knobs, which extend up about 1,500 feet. These knobs, as well as the Crab Orchard Mountains at the head of the valley, are the remnants of the anticlinal mountain that once existed here. In the Crab Orchard Mountains, which rise above the general level of the plateau, we do not get the higher coal measures, but instead the lower ones lifted about 800 feet above their general level in the Southern Tennessee field.

In the coves and passes of these mountains is the only place where limestone occurs on top of the plateau. At one place it forms the floor of a large cove of over 8,000 acres, which is completely surrounded by mountains, and is drained by the waters passing into a large limestone cavern. The exit from this cavern is in the head of Sequatchie Valley, where the water comes out as a large spring.

*Drainage.*—All of the drainage of the plateau is cared for by the tributaries of either the Tennessee or Cumberland rivers. In the field south of the Tennessee Central Railroad, all of the drainage, southeast of a line extending from the Tracy City branch of the Nashville, Chattanooga & St. Louis Railroad to the Crab Orchard Mountains, is into the Tennessee River; the remainder of the plateau is drained by streams flowing into the Caney Fork, a tributary of the Cumberland.

On Walden Ridge, the watershed is never more than a half mile from the escarpment along the Sequatchie Valley, practically all of the drainage going directly into the Tennessee River, through White, Fall, Piney, Roaring, Rocky, Opossum, Soddy, Chickamauga and Suck creeks, and their tributaries. All of these creeks have formed deep and narrow gorges, which wind into the ridge and afford suitable places to tap the coal measures. The early development of the coal fields of Walden Ridge, was due primarily to this fact. The short streams that flow down the west side of the ridge, empty into the Sequatchie River, a tributary of the Tennessee. The long drainage to the east on Walden Ridge, is due to the surface of the ridge being practically a dip slope, extending from the knobs along the Sequatchie Valley to the eastern escarpment, a distance of from eight to ten miles. The water ran down this slope and gradually cut down the deep gorges of the present.

In the northern part of the Sequatchie Valley, the drainage on the western side is as short as on the eastern side, but southward the drainage area increases, the creeks becoming larger. Near the southern end, Little Sequatchie River and Battle and Crow creeks are from 15 to 25 miles long. These flow nearly south and drain the southern part of the Sewanee Basin. The divide between the gorges of these streams flowing

south and the ones flowing north is very narrow and from a half mile to several miles wide.

The drainage of the western edge of the plateau is through Caney Fork, which rises in the northwestern part of Cumberland County; and its tributaries, of which the main ones are Calf Killer, Rocky, Collins, and Elk rivers. These so-called rivers have cut deeply into the plateau, and are the largest and longest streams of the area. The gorge or "gulf" as it is called, of the Caney Fork is deep and narrow, and cuts directly into the heart of the mountains and down through the coal measures into the underlying limestones. In this gorge the Caney Fork flows in places on the surface, in places through underground channels, until it reaches the edge of the plateau, where it is a turbulant stream with a large volume of water, soon to be utilized by the erection of an 80,000 horse-power hydro-electric plant, which will furnish power to the country in a radius of several hundred miles.

Southward along the western edge, the "gulfs" become wider, and long, wide coves, that cut up this part of the field into a dendritic-like area from which much of the coal has been removed, make their appearance. These streams carry large amounts of water in the winter and spring months, but during the summer and autumn become very low, many of their branches on the mountain drying up entirely. Much of the water that falls on the plateau soaks into the ground, and down to the limestone, where after passing through underground channels or caves, it comes out as deep-seated springs. Many caves occur around the base of the plateau, some of which contain deposits of alum, saltpeter and cave onyx.

## GEOLOGY.

*Kinds of rock.*—The Cumberland Mountains, which are the depository of Tennessee's seams of coal, are of Carboniferous age. The rocks are all of sedimentary origin and consist of more or less pure layers of limestone, shale and sandstone. The valleys and lower slopes of the mountains are of limestones and shales interbedded. The upper part of the slopes and the top of the plateau are composed of a series of sandstones and shales. It is in these shales that the coal seams occur. In the southern part of the field the sandstones, shales and coals vary in some particulars from the same measures in the central part of the field, that is, in Cumberland County. In Marion County the lower series of sandstone, shales and coals are well developed, while the higher members have been almost entirely eroded.

In Cumberland County and vicinity, the lower measures are largely wanting. The upper members, which capped only the low hills on the

Cumberland Plateau in the southern section, cover the entire plateau surface in the central part of the field. These upper members contain many coal seams. Several of these seams are workable and well known mines are located upon them.

In the preceding discussion the southern field is shown to differ considerably in its northern and southern parts. In the discussion of the geology and coals, the southern field will be divided into three districts, as follows: Tracy City, Bon Air and Walden Ridge.

*Tracy City district—geology.*—The geology of this region is well shown by two sections, one at Tracy City, the other at Orme. The main rock is a very heavy conglomeratic sandstone known as the Sewanee sandstone about 100 feet thick.

As the Sewanee conglomerate is traced northward, it thickens considerably, and at the falls on Fall and Cane creeks in Van Buren County it is 300 feet thick. Here it is a mass of hard rocks, with a well developed conglomeratic phase. Still further northward from this point, the sandstone divides into an upper and low member, with a 60-foot shale intervening. This was seen in the gorge of Bee Creek at Herbert. On Cane Creek, the 300-foot sandstone mentioned is the first sandstone which occurs above the limestone. The upper 50 or 75 feet of this mass is a soft honey-combed sandstone which contains a large per cent. of efflorescent material, probably epsom salts. Just above the Sewanee conglomerate, lies a shale in which occurs the main coals of this region, called the Sewanee coal. There is sometimes a coal lead directly on top of the Sewanee sandstone. The lower Sewanee occurs 30 feet above the conglomerate, while the upper Sewanee occurs 30 feet higher. There sometimes occurs a thin, shaly sandstone between the upper and lower Sewanee coals. The shale member extends up some distance above the upper Sewanee coal, and is overlaid by an 80- to 140-foot sandstone, which is soft and coarse, and colored red or orange in places.

Below the Sewanee conglomerate, occurs a series of sandstones and shales, which extend down to the limestone, reached at a distance of about 200 feet. The sandstones are non-conglomeratic, hard, and fairly pure. The shales all contain thin seams of coal which come and go. The only place at which any of these lower seams is mined commercially is at Orme, Tenn. This seam occurs directly under the first sandstone below the Sewanee conglomerate. All the other seams are too thin to work.

*Tracy City district—structure.*—The rocks in this region have only very low general dips except along the southeastern edge of the area, where part of the western limb of the low anticlinal fold, which formed the Sequatchie Valley, still remains uneroded and forms the escarpment to the valley.

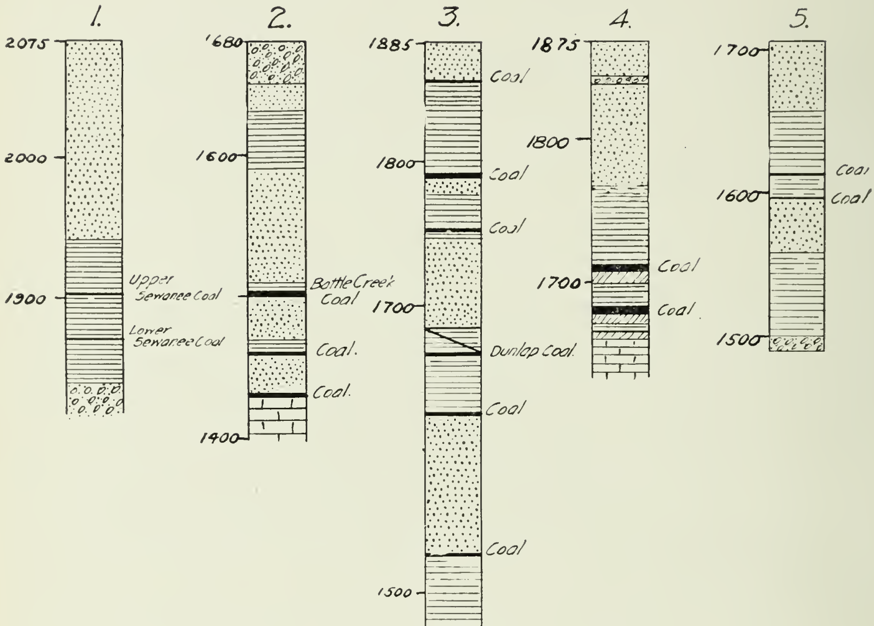
At Altamont in the center of Grundy County, limestone occurs in the bed of a stream, but whether this is due to a fault, or is a lens of calcarious material lying in the coal measures at this point has not been determined.

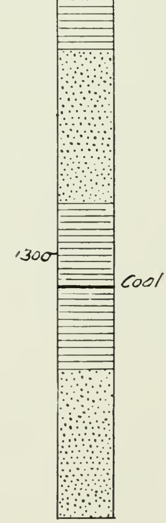
*Bon Air district—geology.*—This region contains a much thicker coal section than the southern area just discussed. Nearly all of the sandstones are conglomeratic in some locality, but often where one of them is markedly so the other members are lacking in this character. Sections at Bon Air, Clifty and Crab Orchard show in general the rocks as they occur in this area.

The section at Bon Air shows the main sandstone of this region. It is a heavy, hard sandstone, about 100 feet thick, with a conglomeratic phase near the top. This sandstone forms a high bluff over a wide area. The pebbles are white quartz and vary in size up to about one-half inch in diameter. Between the sandstone and the underlying limestone, there occurs only one shale, which varies from dark to light bluish-gray. It is in this shale that the well known Bon Air coals occur. The upper Bon Air seam lies 53 feet below the bottom of the overlying sandstone, while the lower Bon Air seam is about 20 feet beneath. There is a third seam at this locality that rests on the limestone which occurs six feet beneath the lower Bon Air coal. It would be well to state that another vein of coal occurs at many places in this locality just below the heavy 100-foot sandstone. This is the Ravenscroft coal.

At Clifty, a mining town in Cumberland and White counties, a good section occurs, which is shown above. The lowest rock is a very heavy conglomerate, which occurs in the bed of Caney Fork River at this point. The limestone comes in just below this sandstone, but it is not seen at this point. Above this is a 60-foot shale, very clayey and bluish-gray in color, which contains red bands of about one inch thickness. It is possible that a coal occurs in this shale near the top. The next member of the series is a 40-foot sandstone composed of thin and heavy beds containing shale partings in its lower half. In color, it is yellowish, with shades of red.

Above this sandstone, occurs a 60-foot clay shale, grayish in color, containing locally a thin sandstone, which appears about 20 feet from the base of the shale. In this shale occurs the workable coal of this locality, which is about 15 feet above the underlying sandstone. This is the Clifty coal. At the base of this shale occurs another coal seam. The next member of the series is a heavy, coarse sandstone, 50 feet thick, which caps the tops of the hills at Clifty. Where none of it has been eroded, it reaches a thickness of 100 feet. From work done by Mr.



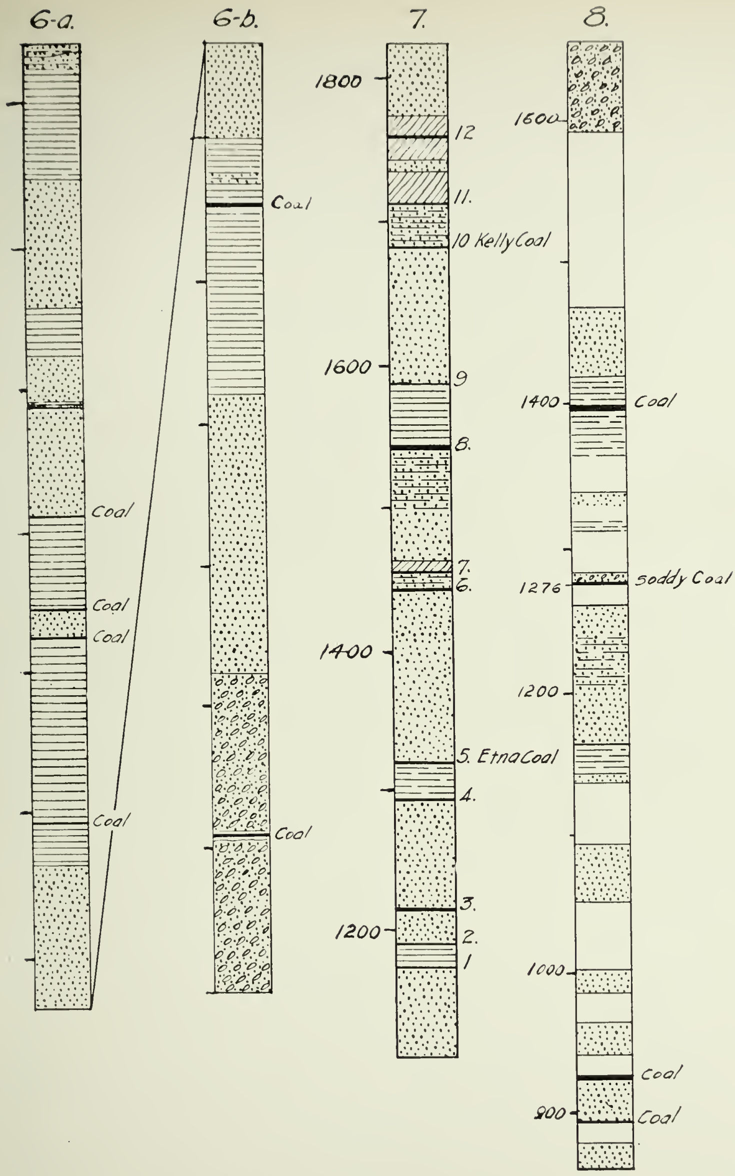

1. Section at Tracy City, Grundy County.

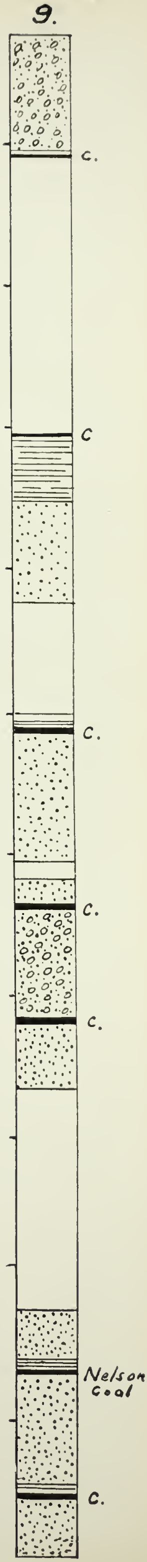
2. Section at the mines at Orme, Marion Co. The upper conglomerate forms to top of the mountain.

3. Section at Dunlap, Sequatchie County, taken up the incline of the Southern Coal Co. to the Dunlap coal. The upper part was seen further back on the mountain.

4. Section from drill hole No. 45 of Bon Air Coal & Iron Co. made near Bon Air shaft mine.

5. Section at Clifty from Caney Fork River to top of Pilot Knob.




6-a-b. Section along T. C. R. R. just west of Crab Orchard.

7. Section up incline of New Etna Coal Co. at Whiteside, Marion County.

8. Section from the top of the mountains back to Soddy mines, and down to the bottom of the incline of the Durham Coal Co., Soddy, Hamilton County.

9. Section at Graysville, taken from Vol. I, p. 120, "Resources of Tennessee."

Chas. Butts of the U. S. Geological Survey and by the author in the summer of 1911, it appears that the Clifty and Bon Air seams are the same.

The sixth section given, was taken along the Tennessee Central Railroad just west of Crab Orchard, Cumberland County, where the rocks are exposed on end, and have dips of from 15 to 75 degrees approximately west. The entire series of the coal measures are brought to the surface and crossed by the railroad in several cuts at this place.

At the base of the section is a heavy sandstone conglomerate, which dips about 75 degrees. Just to the east is a slight fault, and the next rocks seen are the limestones which underlie the coal measures. The upper several hundred feet of the section is composed of a series of clayey sandstones, and sandy shales. The characteristic red or orange color of these sandy shales can not be mistaken after they have once been seen. The top sandstone is the Rockcastle sandstone, mentioned in several of the U. S. Geological folios of this region.

*Bon Air region—structure.*—In most of this region the rocks are nearly level, and the dips are so slight that one can tell that the rocks rise or fall only by comparing their elevation above sea level at points a half mile or more apart. As before mentioned, the rocks along the Sequatchie Valley dip steeply to the west, but they flatten out at a distance of a half mile from the escarpment. From the head of the Sequatchie Valley to Crab Orchard, along the west edge of the Crab Orchard Mountains, the same conditions prevail. The fault which lies on the western side of Sequatchie Valley also extends northeastward along the western edge of Crab Orchard Mountains, and has been noted at several points. Another fault was recently traced and mapped by Mr. Chas. Butts, of the U. S. Geological Survey, and the writer in the summer of 1911. It occurs in Cumberland County and extends in a southwest direction from a point just south of Crossville to near the place where Cumberland, Bledsoe and Van Buren counties meet. This zone of disturbance passes just west of Lantana, Cumberland County, where it is well marked.

*Walden Ridge district—geology.*—This area is a long narrow ridge cut off from the Cumberland Mountains on the west by the Sequatchie Valley, and extending northeast parallel to and along the eastern edge of the Cumberland Mountains to Morgan County. The Raccoon Mountains, which lie just south of the ridge and west of Chattanooga, will also be considered under this head.

In the southern part of this area the sandstones on Walden Ridge have thickened considerably. This is well shown on Lookout Mountain, an outlier of the ridge, where the main bluff is over 200 feet high. On the ridge proper, just north of Chattanooga, the sandstones are still very thick, and at Suck Creek a bluff was noted nearly 200 feet thick. As you

go northward the conditions change and the main sandstones thin considerably.

Sections seven, eight, and nine show to best advantage the conditions as they exist in this area.

The Etna section was made along the incline of the New Etna mines at Whiteside, Marion County. The lowest rocks here exposed are thin beds of sandstone and shales with a few thin coal seams. The Etna coal, the first coal worked, occurs in the lower half of the section at the base of a heavy sandstone about 100 feet thick, which here stands out as a high bluff. Several feet of thin-bedded, hard flagstones lie at the base of this thick bedded sandstone. At the point where this section was made, there were no signs of a conglomeratic phase, but about one mile from here two such well marked bands were found near the base of the bluff. They were approximately four feet thick, and separated by about 15 feet of sandstone. The gray shale in which the coal occurs, is sandy in places, and has a slaty appearance. Below this is a thin-bedded, whitish-gray, pure sandstone. About 150 feet above the top of the first heavy bluff, another bluff-forming sandstone occurs. Between these two bluffs are a few sandy shales and shaly sandstones. A heavy-bedded, massive sandstone about 100 feet thick composes the upper bluff. It is coarse grained and soft in many places, and has a yellow color, which occasionally has a reddish tinge. Directly on top of this upper sandstone bluff occurs the Kelley coal, the principal seam of this region. Two other coals lie in this 80-foot shale, whose lower part is very sandy. The next member of the series is a heavy 50-foot sandstone, which caps the hills at this point. There are twelve seams of coal that were noted in this section.

The Soddy section was made up the incline to the Soddy mines, and from thence along the road to the top of the mountain. The lower 300 feet of the section is composed of thin, alternating beds of sandstones and shales. These thin, white, or light-yellow sandstones are often either rippled-marked or cross-bedded. The shales, which contain a few thin coals, are often sandy and generally have a yellowish-gray color. Above this series is a thick 100-foot sandstone, the lower 40 feet of which makes a thick, cross-bedded, hard, sandstone bluff. The upper part of this bed is composed of a thinly laminated cross-bedded sandstone with shaly streaks intervening. The next member of the section is a thick, bluish-gray, clayey shale containing the Soddy coal, which occurs 15 feet above the underlying sandstone. The lower 50 feet of this shale, contains several thin sandstone bands. Above this is a thin sandstone, overlaid by about 60 feet of iron-stained gray shale, partly sandy, and partly clayey. Twenty feet from the top of this shale is a coal seam. Overlying the shale is a hard, cross-bedded, yellow sandstone, 50 feet thick, which some-

times forms a low cliff. This is followed by 120 feet of covered mountain side, which is probably a sandy shale. Above this and capping the mountain is a heavy and massive yellowish-white, bluff-forming sandstone conglomerate. It is full of white quartz pebbles, up to an eighth of an inch in diameter, and in places, the upper portion of the bed shows a few mud cracks.

The last section is one taken near Graysville, where they are mining the lower measures, and is very similar to the one at Soddy. A description of this area occurs in Volume I, *Resources of Tennessee,* pages 117 to 163.

*Walden Ridge—structure.*—The rocks of the ridge have a gradual southeastward dip from the Sequatchie Valley, where the layers of sandstones and shales are steeply upturned toward the west. One-half a mile from this valley escarpment the rocks appear to lie flat, but at that point an almost perfect dip slope sets in across the ridge, which extends within one mile of the eastern bluffs, at which point the rocks are 300 feet lower. Again on the eastern edge of the ridge the rocks have steep dips, but in a northwestern direction. Walden Ridge is really a syncline with a long western and short eastern slope. On account of this eastern slope, the mines on the eastern side are located in the heads of the ravines where the rocks are more level.

## COAL VEINS.

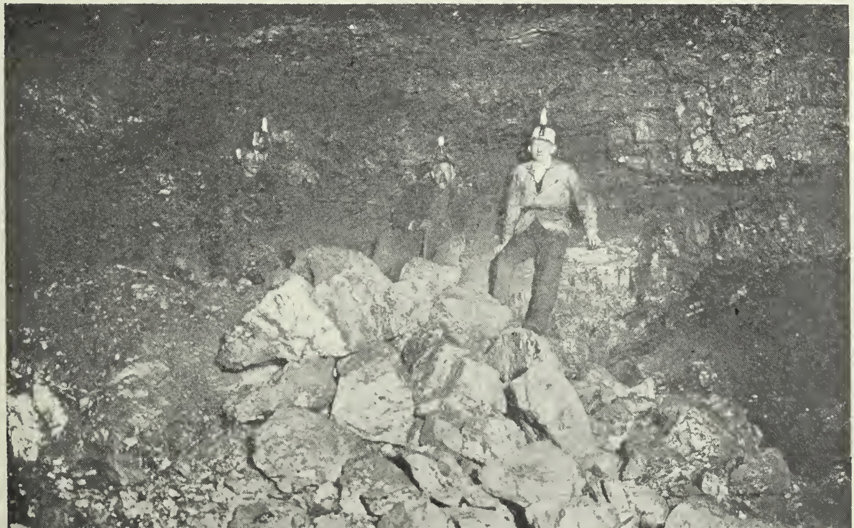
### TRACY CITY DISTRICT.

In this report the Tracy City district includes all of Grundy County and parts of Bledsoe, Franklin, Marion and Sequatchie counties. The reason for thus grouping them is that the coal development in these southern counties has all been partly correlated with old workings at Tracy City, where the Sewanee coal is mined.

*Workable seams.*—In this area the Sewanee coal is the main workable seam. The only other seam worked south of Tracy City is one of the lower veins known as the Battle Creek coal. These two coals are easily located, for their horizon varies very little.

*Sewanee coal.*—The main Sewanee seam occurs about 50 feet above the top of the only heavy sandstone conglomerate of this area. This sandstone is here coincident with and forms the surface of most of the general plateau, and on it lies numerous low hills, the only remnants that are left of the higher measures. It is in these hills that the Sewanee coal seams are found. Only the upper vein, which varies greatly in thickness, is worked. Although many measurements show the seam to be five or six feet, and some as high as ten or more feet, the general average is

Entrance to Battle Creek Coal Co.'s mine at Orme, Tenn.



Inside of mine at Orme, Tenn., showing 20-foot vein of coal.

from three to three and a half feet. The floor of the seam is a very plastic grayish-white clay, or a gray shale. Above the seam is a very fossiliferous gray shale, carrying a large variety of plant impressions.

*Battle Creek coal.*—The horizon of this coal, as already mentioned, is at the base of the first heavy sandstone below the Sewanee conglomerate, which also forms the main bluff in the southwestern part of the coal field. This seam is one of the most uncertain veins worked in Tennessee, for it varies greatly in thickness, changing in a few feet from the thickness of a pencil-mark to a 20-foot vein. The troughs in which the coal occurs extend in a direction north 50 degrees east. In places the coal in the rolls is solid, but at other points the hard coal is divided into four benches of about the same thickness, separated from each other by an inch or two of soft bony coal. At the base of the lowest hard coal bench, there occurs in places a bench of soft coal which varies from nothing to two feet in thickness. Again small lenses of cannel coal occur, entirely surrounded by the hard coal. There is very little kidney sulphur present, but sulphur occurs in the form of flakes. The coal is hard bituminous, and shows practically no slacking on exposure.

The roof of the seam is hard, fairly pure sandstone, while the floor is sandstone where that is not overlaid by several feet of grayish-white clay. This clay occurs as a rule where the coal is thin, and even then it often is lacking. The horizon of this coal underlies the whole southern part of the plateau and has been widely prospected, but has not up to the present been found in quantities favorable for mining, except at Orme, Tenn.

Some other coals are worked in this district, but as this is done only in Bledsoe County, these seams will be described under the description of that county. They are the Richland, Morgan Springs and Angel coals.

## EXTENT OF COAL MINES.

*Bledsoe County.*—This county is divided into three sections extending in a northeast and southwest direction; they are the western third, located on the Cumberland Mountains, the central third in the Sequatchie Valley, and the eastern part on Walden Ridge. The horizon of the Sewanee coal underlies most of this county on the Cumberland Mountains. Active mining is carried on only at Atpontley, in the southern part of the county. The rocks at this point dip somewhat, and as in other places on the edge of Sequatchie Valley, mining conditions are far from ideal.

The coal, which is somewhat mashed, ranges from three inches to six feet, and contains a clay parting which varies from one to twelve inches. This parting occurs anywhere from the top to the bottom of the seam. The coal is probably the Sewanee seam.

The area around Pikeville recently has been thoroughly discussed by W. C. Phalen, of the U. S. Geological Survey, in an article which appeared in Volume I, No. 4, *Resources of Tennessee,* which can be obtained from the State Geologist. The Richland and Angel coals are the main veins described in this paper. The Richland is probably the same as the lowest Sewanee coal, as it occurs directly on top of the Sewanee conglomerate, while the Angel coal occurs just below that formation and is a very persistent seam. The Morgan Springs coal, which lies directly under the upper cliff-forming sandstone has not exceeded two feet in thickness wherever prospected. It is a good clean coal, and may occur in some localities in workable thickness. The Angel bed is being worked in an 8-foot vein on the Stephen Gap road, in Bledsoe County, just below the county's northern line, where it is mashed and dips about 25 degrees. The Richland coal is only about two feet thick around Pikeville. The main or upper Sewanee is the principal coal and has been opened in numerous places, along the western boundary of the county, where the seam is well developed, and shows from three to four feet of coal in many prospects.

On the State coal lands of the Herbert Domain, in the northwestern part of the county near Herbert, the coal in one opening shows a thickness of 71 inches, but at this point the rocks are slightly mashed and the thickness of the coal is abnormal.

*Franklin County.*—The Sewanee coal occurs in this county only in three comparatively small hills between the town of Sewanee and the county line just east of it. The Nashville, Chattanooga and St. Louis railroad cuts through a sag in one of these hills, at which point the coal outcrop can be seen. Practically all of the coal has been worked out of these hills, and the mines abandoned. It is from these deposits that this coal gets its name, although the original Sewanee mines were in the coal seam at present called the Battle Creek coal.

Several spurs of the Cumberland Plateau, which contain the coal veins below the Sewanee conglomerate, extend out into Franklin County. Such is the spur up which the Nashville, Chattanooga and St. Louis railroad branch line from Cowan to Tracy City runs, and on which the town of Sewanee is located. The one of the ramifications of this ridge which extends south from Sewanee along the county line, also contains the Battle Creek seam. West of the main line of the Nashville, Chattanooga and St. Louis railroad from the Cowan tunnel to the Tennessee-Alabama state line, are some outliers of the Cumberland Mountains, which are capped by the lower coal measures in which the Battle Creek seam has been prospected, without success.

*Grundy County.*—All of the county that lies on the plateau is underlaid by the lower measures, which contain several seams, none of which

have been found workable. The Sewanee coal is worked extensively in this county, at Tracy City, Coalmont and Clouse Hill. The main operations are now at Coalmont and around Tracy City. Circling around the eastern side of Tracy City and from there extending northward about six miles is a long narrow ridge, which at its end spreads out and covers several square miles, and is underlaid with the Sewanee coal. The mines at Coalmont are situated at its northern end. East of Coalmont and along the county line is an area in Grundy County a mile or more wide, which also contains the Sewanee coal. The lack of a railroad in this territory is all that has prevented the development of this section.

*Marion County.*—The part of this county that lies on the Cumberland Mountains is greatly cut up by the ravines and coves which ramify back and forth into the plateau. The upper measures have been eroded away from most of this county, but two small areas occur on the promontory between the Little Sequatchie River and Fiery Grizzard Creek. The road from Sequatchie to Tracy City passes over one of these areas, while to the other there is an extension of the Nashville, Chattanooga and St. Louis railroad from Tracy City. A large area of Sewanee coal exists in the northern part of the county on the spur of the mountain between the Little Sequatchie River and the Sequatchie Valley. The mines at Whitwell are located on this area. There is a large body of coal in this region, and development is only held back by lack of transportation.

The Battle Creek coal is worked at Orme, Tennessee, in the southwestern corner of the county, as has already been mentioned. In the past, a number of mines have operated on the coal in this area, which is that part of the Cumberland Mountains which lies from South Pittsburg west to the county line.

*Sequatchie County.*—This county is divided into three natural divisions by the topography of the region. The western third lies on the Cumberland Mountain, the central third lies in the Sequatchie Valley, and the eastern third on Walden Ridge. The Sewanee seams occupy practically the entire part of the county that lies on the mountain. Drill records show a vein of good thickness. Mining is carried on at only one place, Dunlap, where the coal is 48 inches thick. At the mine entrance the seam is split by an 18-foot clay lens, which thins down to three inches toward the north and disappears entirely towards the west. A section is given at this point on page 32, which shows rashy coal 40 inches thick just above the heavy Sewanee conglomerate. At a distance of 40 feet above the conglomerate, the main Sewanee seam occurs. Instead of the sandstone above this shale capping the highest hills of the mountain as it does around Tracy City, the measures rise higher, and one finds at this point another thick shale in which three coal veins occur. The lower of these

seams lies directly on top of the first sandstone above the conglomerate, and at this point measures 18 inches. Thirty-five feet higher, occurs the second seam, which is 20 inches thick, but made up entirely of rash coal. At the top of this shale about 70 feet higher, is the third seam, containing 18 inches of coal, directly underlying the cap rock of the mountain, which is a soft, white, coarse sandstone. North from this county the same conditions prevail. These upper coals are found in many of the hills while those below the Sewanee conglomerate, as elsewhere, occur in irregular pockety seams.

### BON AIR DISTRICT.

This District is comprised of that part of Cumberland and Putnam counties south of the Tennessee Central Railroad, and the part of Van Buren and White counties that lies on the plateau.

*Workable coals.*—The main coals of this area are the Bon Air coals. They are extensively mined at and around the town of Bon Air, where they occur in the shale under the first heavy bluff-forming sandstone. At the top of this shale the Ravenscroft coal occurs.

*Ravenscroft coal.*—The Ravenscroft coal, which averages 54 inches, is a hard, bituminous coal, containing some sulphur, and makes an especially good domestic fuel. It is covered by a sandstone roof and has a bluish-gray, clay floor. In places there occurs several inches of rash at the base of the coal.

*Bon Air coals.*—There are two Bon Air coal seams, an upper and a lower, which are separated by about 20 feet of clay and shale. In places the upper seam is worked, and again it is the lower vein which is the thicker. Often there is a third seam, or one might say an under rider of the lower Bon Air, which occurs five or six feet below it and is separated from it by clay. This seam rests on limestone, or is separated from it by a foot or two of clay. From field observations it appears that where one of the Bon Air coals occurs in workable thickness the other is too thin to be utilized. In the shaft mine the seam averages 36 inches. It must not be thought that the only coal found immediately above the limestone strata is the Bon Air, for this is not so. The line of contact between the limestone and the overlying coal formation is a line of unconformity. That is, the rock series is broken, and some of the members are missing, because they were never laid down. In this manner as one travels from the south to the north, it is seen that the lower coal measures are gradually cut out. For example, the coals that lie next to the limestone along the State's southern line are many feet lower stratigraphically than the coals that lie next to the limestone along the Tennessee Central Railroad.

*Sewanee coals.*—At Eastland and Clifty, situated along the Cumber-

land-White County line, the coals mined in the top ridges are called the Sewanee coals. There are two veins which occur at this point, the lower one occurring directly on top of the sandstone upon which Clifty is built, and the upper one about 15 feet higher and separated from it by shale. The upper coal, which is soft and slacks very easily, is the main seam and is the one generally worked. It contains too much sulphur to permit of making commercial coke. At Eastland the seam averages 48 inches, and has a bluish-gray shale roof, and a gray clay bottom. At Clifty, about a half mile distant, the coal in one of the mines averages 48 inches and 42 inches in another. The floor of the seam is gray clay, and the roof is bluish-gray shale or a thin sandstone.

The Morgan Springs coal, which is of good quality and clean, has been worked in a few local banks, but is too thin to mine commercially.

*Cumberland County.*—This large county is divided by the Tennessee Central Railroad in a northeastern and a southwestern area of nearly equal size. The southwestern area only will be discussed in this article. The remainder of the county is described in the companion article, by Dr. L. C. Glenn. The eastern edge of the county lies along the Sequatchie anticlinal fold, which forms the Sequatchie Valley and Crab Orchard Mountains.

The coals along this line have been worked locally; but as the rocks have dips which range from 15 to 75 degrees the mashing is so great, that all the mines opened in this area have been closed. In the section given along the Tennessee Central Railroad just west of Crab Orchard, the thickness of the different coal outcrops from the bottom to the top are as follows:

A lead that had somewhat the appearance of coal was noted in a much mashed five-foot shale which occurred in the middle of the lowest conglomerate, where the dip was 70 degrees.

The next coal, which measured 20 inches and occurs in the first shale, was being opened at the time this locality was visited. This seam, which is probably the same as the coal at Monterey, is said to vary from 18 inches to five feet.

The next or second shale contains two coals, one 30 feet from the bottom and the other at the base of the overlying sandstone, which has a dip of 25 degrees. The thickness of the lower coal is 36 inches, while that of the upper is 12 inches. In the third shale, there are also two coal horizons, one occurring at the top and the other at the bottom. The coal at the lower horizon is 16 inches thick, and has a sandstone bottom and shale roof. The upper coal horizon, at the base of the overlying sandstone, shows only a thin coal blossom. The two higher shales at this point do not show any coal horizons.

About one mile west of Crab Orchard these measures flatten out. The upper sandstone of the Crab Orchard section covers a large part of the surface of the plateau in this county, but along the southeastern border only the lower 200 feet of the coal measures remain. There is also a low anticline occuring southwest of Crossville, accompanied by faults. The main fault starts one and a half miles east of Legget and extends about eight miles in a general direction south 60 degrees west, passing about one and a half miles west of Lantana, and one mile south of Pott's Knob, and Flat Rock school house. From this last point it has been traced about eight miles further in a direction of about south 30 degrees west, passing just east of Thomas Spring School, and leaving the county at a point about two and a half miles west of Newton.*

There are also two small faults about four miles long which run roughly parallel to the main fault, one to the east of it, and one to the west. The eastern one runs about one-half mile west of Lantana, and the western one extends from about one-half a mile south of Legget for a distance of four miles, the other end being one-half a mile south of Anderson Knob. The region of these faults is naturally somewhat disturbed, and was first recognized by Safford many years ago at Lantana, where a bed of mashed coal was mined by stripping off several feet of soil under which it occured. Where the formations are undisturbed in this region, the main coals lie from two to six hundred feet under the surface, and not much is known concerning them, as very little drilling has been done.

*Putnam County.*—Only the eastern edge of this county lies on the Cumberland Mountains, and but part of it is south of the Tennessee Central Railroad. At Monterey the section is somewhat similar to that at Bon Air. The one heavy conglomeratic sandstone present forms massive bluffs at this point, is the surface rock on the border of the plateau, and has a seam of coal at its base. Eastward some of the upper sandstones and shales appear, and at Dripping Spring there are about 200 feet of sandstone and shale present above the heavy bluff sandstone which occurs at Monterey. The main coal occurs under the bluff at Monterey, and is probably the same as the Ravenscroft seam. Several inches of rashy coal at the base of the soft, red conglomerate, upon which Dripping Spring is situated, was the only other vein noted.

*Van Buren County.*—The coal resources of this county are entirely undeveloped and the only mining is from small banks and for local use. The western part of this county, and especially the southwestern corner, is underlaid by one or more rich veins of coal, while around the post-office

*This was observed in working the geology of the Crossville folio, which will be published by the U. S. Geological Survey.

of Gillentine in the southern part of the county, numerous openings have been made on the coals, which show that several seams are of workable thickness. A bank about one mile north of Gillentine, which is said to be on the Sewanee seam, shows 44 inches of coal, and has a roof of eight inches of shaly clay covered by a thin sandstone. This is a coal which shows little weathering, and has a small cubical cleavage.

At Rovertson Springs is an opening which measures 54 inches; on Glady Fork one that measures 52 inches; while at the Oleo post-office a prospect shows 48 to 52 inches of coal, all supposed to be on one of the Sewanee seams. They lie above the heavy sandstone which forms the mountain escarpment just west of this area, and probably correspond to the coals worked at Sewanee.

Under the bluffs which occur around the head of Rocky River and its tributaries, openings have been made on what is probably the equivalent of the Ravenscroft seam. One of these openings, which was made where the water of Double Branch falls over the bluff, shows a 38½-inch seam, divided into two benches. The upper bench consists of ten inches of hard coal, separated by 13 inches of slate from the lower bench, which contains 16½ inches of good coal. These measurements were taken at the outcrop. It is said that the slate thins down to several inches at the end of the drift and that the coal thickens. The roof of this seam is hard sandstone and the floor is clay.

Around the town of Spencer, these upper and lower seams occur in about the same thickness as at the points just mentioned, and coal from them is used locally.

*White County.*—Only the eastern part of this county, contains the coal measures of the Cumberland Plateau. The main mines on the Bon Air seam occur around the town of Bon Air, while in the northeastern corner of the county the Ravenscroft coal is worked. At Eastland and Clifty, on the middle-eastern border, the supposed Sewanee seams are operated. These localities have already been taken up under the head of "Bon Air district" on page 41, in the description of the type seams of coal.

On the U. S. Geological Survey areal map of the Pikeville sheet, the country where the present Clifty extension of the Nashville, Chattanooga and St. Louis railroad crosses Clifty Creek, is shown as containing only the lower coals, but recent work has proven that the upper coals occur. The rocks are somewhat disturbed at this point and have local dips of 5 to 10 degrees, and a slight fault may probably exist. A coal probably in the first shale above the Bon Air coals, has been opened at this point and shows a thickness of 24 inches, with a one-inch parting near the center. In the shale above this one, another coal, which shows a thickness of from 25 to 38 inches, has been opened up in several places. One of

these prospects which occurs on the side of the Eastland hills just above the Nashville, Chattanooga and St. Louis railroad is as follows: Clay shale roof, 23 inches of coal containing kidney sulphur, five inches of rash, and a floor of gray clay. A coal is exposed under the falls of Jennings branch, which is near Stringtown. The seam has a sandstone roof, slate bottom and is 45 inches thick. Its section follows:

| | Inches |
|---|---|
| Soft coal | 19 |
| Rash | 1 |
| Cannel coal | 21 |
| Soft | 4 |
| Total | 45 |

The limestone outcrops 20 feet below the seam. These few localities cover the county and show in general the condition of the coal measures.

## WALDEN RIDGE DISTRICT.

*Coals of Raccoon Mountain.*—The coals of the Walden Ridge district have been mined in many different localities and for many years. There are at least twelve coal horizons, but often many of them are wanting, and only one or two of those that remain are of workable thickness. These seams, where they occur on the New Etna Company's property at Whiteside, have all been named. In the section at that point, given on page 33 the coals are numbered, and these numbers will be used in referring to them. Number 1, the Mill Creek seam, is a very rashy coal about four feet thick with a clay parting, which varies from one to six inches in thickness in the middle. The coal above this parting is not very rashy. Number 2, the Red Ash seam, occurs 42 feet above the Mill Creek vein. It is a very good, clean coal from 4 to 30 inches thick, which on burning leaves a red ash. Number 3, the Dade seam, occurs about 25 feet above the Red Ash. It was covered at the time of the visit, so no measurements could be taken, but is here a thin coal. Number 4, called the Battle Creek coal, is clean, hard coal, which has a thickness of 14 inches, and a shale roof and bottom. Number 5, the old Etna coal, was the original coal mined at this point. It is hard, pockety coal, which shows little weathering and varies from two inches to seven feet in thickness. The top of the seam is the base of the lower cliff-forming sandstone, while the bottom is shale or clay. Number 6, which has no name, is only a thin coal blossom, which occurs on top of the sandstone just mentioned. Number 7, which is called the Whitwell seam, occurs about 15 feet above No. 6, but no measurements could be taken, as the coal was not opened. Number 8, called the Weddell seam, is a soft coal, which measures eight

inches, and has a 30-inch white clay bottom, and a dark bluish-gray shale roof. Number 9, the cap seam, which measures only six inches and has a sandstone roof and bottom, lies directly under the second bluff-forming sandstone.

*Kelley coal.*—Number 10, the Kelley coal, which is very soft, tender coal that breaks quickly into small cubes, averages 32 inches and is the only coal mined at present. It occurs directly on top of the sandstone just mentioned, and has a sandstone bottom and gray clay roof. It is known especially as a blacksmithing coal.

Number 11, called the Durham or Craven seam, occurs 35 to 40 feet above the Kelley coal. The vein consists of two benches, each from 12 to 18 inches thick, separated by one to two feet of hard shale. The upper bench is somewhat like the Kelley coal, but the lower bench is very rashy. Number 12, the Oak Hill seam, varies from 18 inches to five feet in thickness, and contains a large amount of kidney sulphur. It is about 25 feet above No. 11, and is the topmost seam at this point.

It is thought that the Kelley coal corresponds to the lower Sewanee and Soddy coal, but it may be higher. The seams which are here called by the miners the Dade, Battle Creek and Whitwell, probably do not correspond to these coals at their type locality.

It is said that there are two thin coal seams which occur below seam No. 1, the Mill Creek vein.

*Walden Ridge coal.*—The main coals worked on the Ridge proper are called the Soddy, Richland, Angel, Nelson and Goodrich.

*Soddy coal.*—The lower Soddy and Richland coals are probably the same, and are thought to correspond to the lowest Sewanee seam. The Soddy coal at Soddy averages 34 inches, but varies from ten feet to nothing. It has no butts or faces, weathers easily, and when washed makes good coke. The roof is of very fossiliferous shale, and the bottom is in places hard, white clay with plant impressions, but where this is wanting, the floor is of sandstone. An average section is as follows:

| Blue slate roof | Inches |
|---|---|
| Rash | $\frac{3}{4}$ |
| Coal | $32\frac{1}{4}$ |
| Rash or bone | $\frac{1}{8}$ |
| Soft coal | 4 |
| Hard, gray clay, fossiliferous | .. |
| Total | $37\frac{1}{8}$ |

The lower 12 inches of the seam contains a very little kidney sulphur, some of which reaches six inches in diameter.

*Angel coal.*—The Angel coal, which is described under the Tracy City

district as occurring at the base of the Sewanee conglomerate, is not worked on the ridge at any point, but is at a horizon that should be carefully prospected, as it may occur in workable thickness.

*Nelson seam.*—The Nelson seam, which is the next to the lowest coal worked, and the most important of the lower coals, was first mined at Dayton. It occurs in places as one bench, in others as two, separated by a thin parting of bone or clayey shale. It is very soft, in places dirty, and has an average thickness of about 40 inches.

*Goodrich coal.*—The Goodrich coal, which contains practically no rash or bone, occurs about 30 feet below the Nelson seam, is the lowest coal worked, and averages 24 inches or less in thickness. At places in this district, a coal called the lower Nelson is mined. This occurs about 20 feet below the Nelson seam, and may be the Goodrich bed.

*Bledsoe County.*—The eastern part of this county lies on Walden Ridge. Along the western edge of the ridge the rocks are upturned, as has already been mentioned, and the coals occur under conditions very unfavorable for mining. The Morgan Springs coal outcrops on top of the Ridge in many places, but it is only locally mined, as it has never been seen with a thickness of more than 24 inches. The outcrop of the Richland coal has been noted in several places, and it is worked locally.

Several coals occur under the Richland outcrop on the side of the ridge, and although these seams have been opened for local use, most of them were soon abandoned, on account of the mashed conditions of the rocks. The remaining part of this county is described on page 38.

*Hamilton County.*—The western half of this county lies on Walden Ridge and is practically all underlain by good coal. Mines are located every few miles along the eastern escarpment of the ridge. Most of these mines work the Soddy or Richland coal and the lower Nelson seam, and have been in operation for a number of years. At Montlake, the coal mined is probably the Soddy seam, as it lies directly on top of a heavy bluff-forming sandstone, which appears to be identical with the one under the Soddy mines. The coal, which is free from rash, and weathers very little ranges from five feet to thirty inches in thickness, with an average of 36 inches, and often has an inch or two of bone at its base. In places there is a little kidney sulphur in the middle of the seam.

There are several large mines at Soddy, which work the Soddy coal. Data for the type description of the Soddy coal, which is given on page 46 was secured at these mines.

The Sales Creek mines are operated on the lower Nelson seam, which is separted from the upper Nelson coal by 38 feet of shale. This lower Nelson may be found to be the same as the Goodrich bed. A section of the coal seam worked is as follows:

| Gray-blue shale roof | Inches |
|---|---|
| Rash | 3 |
| Coal, much pyrites | 9 |
| Rash | 1 |
| Coal, much pyrites | 17 |
| Rash | 3 |
| Coal, very little sulphur | 12 |
| Rash | 3 |
| Coal | 6 |
| Clay shale bottom | .. |
| Total | 54 |

The average thickness of the coal is 38 inches, and it is used in the making of coke.

The entire western part of this county is underlain by at least two good seams of coal. The upper or Soddy coal is workable in most places, while the lower one, the Nelson. is well developed in the northern half of the county and may be locally mined towards the south.

There are several other seams of coal that occur in this county, but so far none of them have been found workable.

*Marion County.*—At present all the mining that is being done in the eastern part of this county is at Whiteside, where the New Etna mines are located. The coals that occur at this point have already been described on page 45. The old Etna seam was worked in the past on the McNabb property, situated just across the Tennessee River from the New Etna mines. Some mining was done along the east side of the Sequatchie Valley in this county, but this has all been abandoned. The two main coals are the Kelley seam, which is worked at the New Etna mines, and the Etna seam, which in the past was extensively mined up and down the river. At the time of the Civil War the U. S. Government had some mines located on this seam.

*Rhea County.*—The western half of Rhea County lies on Walden Ridge and is underlain by several good seams of coal. The ones mined are the Richland or Soddy coal, and the Nelson and Goodrich coals. At present the work is confined to the southern end of the county around the towns of Dayton and Graysville.

The mining at Graysville is on the lower Nelson seam, at which point the coal varies from 10 inches to seven feet in thickness, with an average of 24 inches. It has a slate roof and a hard, sandstone bottom, both of which are very irregular. The thick coal runs in parallel troughs about 150 to 500 feet wide, having a general direction of south 60 degrees west. When the coal in these troughs reaches more than four feet it begins to get dirty.

At Dayton, mines are operated on the Richland and Nelson seams, the main ones being in the Richland coal. This is the first place that the Nelson coal was mined. A detailed description of the mining around this town is given in an article on the coals of the Dayton-Pikeville area, which appeared in Volume 1, No. 4, of the *Resources of Tennessee,* and which can be obtained by writing the Tennessee Geological Survey.

At Morgan Springs, situated back on the top of the ridge, the Morgan Springs coal outcrops, showing a thickness of about 24 inches.

In the northeastern part of the county, no mining is done except locally. The rocks that occur here comprise the western side of the Crab Orchard Mountains, and their tilting has been such as to mash the coals badly in many places. At Grand View, coal from one of the upper veins, probably the Soddy, is mined for local use. It is mashed somewhat. In the past, some mining was done at Roddy, but was abandoned on account of unfavorable conditions of the rocks.

*Sequatchie County.*—The eastern part of Sequatchie County lies on Walden Ridge. The same conditions prevail in regard to structure, and the occurrence of coal, as in the parts of other counties that lie on the western side of the ridge. The dipping of the rocks back from the valley, and the absence of gorges in which openings could have been made, has prevented any mining in this section of the county.

# The Importance of Saving Our Soils*

By A. H. Purdue.

The approximate area of the earth is 197 million square miles. About one fourth of this, or approximately 49 million square miles, is land. A large per cent. of the land is located in the cold regions of the North, and is unfit for cultivation. Another large per cent. is located in the densely forested regions of the tropics, and probably can never be successfully cultivated. Another large per cent. is in mountain regions that are too rough and rocky for agricultural purposes. Still another large per cent. is in arid regions.

Only about one third of the land area, or approximately 16 million square miles, receives an annual rainfall between 20 and 60 inches. A smaller annual rainfall than 20 inches makes a region arid or semi-arid. A region with an annual rainfall of more than 60 inches is not well suited to agriculture.

Quite a per cent. of the land area receiving more than 20 inches annual rainfall is mountainous and is largely unfit for agriculture; but on the other hand some of the semi-arid land can be used for farming purposes by the process of dry farming or by irrigation. While I am not able to give you a close estimate of the amount of tillable land upon the surface of the earth, it appears that 20 million square miles would be liberal.

Though you have often heard the statement that the soil is the chief source of subsistence, it is not out of place for that to be repeated here, or on any other occasion where the object is to impress people with an idea of the true value of land. While we are not accustomed to think of them as such, air and water are important foods. These, with common salt and fish, constitute practically all of our food material that is not taken from the soil. Most of our food comes indirectly from the soil, through plants and animals. The soil is absolutely necessary for the existence of man; and its total depletion would mean the extermination of the human race.

For all practical purposes relating to the future of mankind, we may say that the land area of the earth, and consequently the soil area, is fixed. On the other hand, the population of the world is rapidly increasing.

*Abstract of a talk before the Middle Tennessee Farmers Institute, December 5, 1912.

From the best estimates that can be made, the present population of the world is about 1,600 million. With an area of 20 million square miles of land that can be successfully cultivated, this is an average of 80 people to the square mile. It is said that the population of the world has increased 250 per cent. in the last hundred years. If the increase of population for the next hundred years is as great, there will be an average of 280 people for every square mile of good agricultural land. This means that if the average person consumes as much a hundred years from now as at present, 35 head of stock will have to be produced where now ten head are produced; that 70 bushels of wheat must be grown where now there are 20; that 140 bushels of corn will have to be grown where now there are 40; and that 350 bushels of potatoes will have to be grown where now there are 100. A hundred years is only a short distance in the future. At the present rate of increase of the world's population, or even at a greatly reduced rate, what will be its population 200, 500, 1,000 or 5,000 years hence?

All the foregoing statements are made that we might get some idea of the real value of an acre of land; but its true value can not be appreciated until we consider the origin of the soil. The limited time at my disposal will permit of my saying only a few words on this subject, with the hope of impressing the idea that the process is a very, very slow one. Soil is only finely broken up rock, mixed with a small amount of humus. The breaking up of the rocks is brought about by temperature changes, by the roots of plants, by the work of animals, by ice formed within the rocks, by water moving through them, and in other ways.

While rocks are being changed into soil, a portion of the soil is removed from hill slopes by the wind, and by the water running over the surface. The thickness of the soil upon hill slopes, is the difference between what has been formed by the rock disintegrating processes and what has been washed away. While our hill slopes were covered with forests, the roots of the trees, and the decaying leaves reduced the hillside wash to the minimum. When the hills were cleared of their forests and placed under cultivation, the amount of wash was at once changed from the smallest amount possible to the largest amount possible.

Strange at it may appear, the people of the United States have not until just recently become aroused to the importance of saving their hillsides from wash; and an idea of the importance of doing this is not yet nearly as prevalent as it ought to be. We have heard a great deal within the last few years about conservation of coal, oil, gas, timber, and water power. There is no means of comparing the relative waste of these products to that of soil from hillside wash, but I have no doubt that the

waste now going on from washed soil is greater than the waste from all other things combined.

It probably is no exaggeration to say that in West Tennessee there are hundreds of thousands of acres that not many years ago were in a good state of cultivation, but are now so gullied as to be entirely worthless and are thrown out on the commons. It has not been long since a man told me that only a few years ago he purchased 1,500 acres of this land at 60 cents an acre.

The land of Middle Tennessee is not gullied like that of the western part of the State, but I suspect the actual loss from waste is equally as great, and is much more serious. It is more serious for the reason that the soil of the Central Basin is thin. The rocks on an average are only a few feet from the surface. In many places, the soil has already been removed down to the rocks, rendering the land worthless. The Central Basin of Tennessee has long been considered, and rightly so, one of the most prosperous parts of the South. It can not continue as such, unless the farmers of the region see to it that the deplorable waste from wash is stopped.

It is not possible in a short talk to consider methods of preventing wash, but if I only in a measure impress upon you the importance of doing so, the purpose of my talk will have been realized. Remember that wash is produced by the water that runs over the surface, known as *run-off*. The way to prevent the wash is to stop the run-off. One means of doing this is to plow deep. This reduces the run-off, because it loosens up the ground to considerable depth and permits the water to soak in. The furrows should not run up and down slopes, but should be parallel with the bases of the hills, or as we say, with the contours. If a gully starts on the hillside, stop it at once. The means are usually simple, and are known to all of you. Put a little brush or straw at the mouth to catch the wash, and another small amount at the head to stop it from working back. Where it is necessary to do so, sod the gully over with grass, such as Bermuda, Japanese clover, or red-top. In those cases where simple means will not prevent water from collecting along the lines of the gullies, a drain tile may be put in along the bottom of the gully extending down the hill and opening out at some desirable place. This will prevent the wash, by carrying off the water beneath the surface, instead of on the surface.

Terracing in another means of preventing wash, but farmers do not take to it, because of the inconvenience in farming produced by the terraces. The soil of hillsides of average slopes can be saved without terracing, but it is necessary on steep slopes, and the sooner it is resorted to the better.

If our soils are saved from destruction by wash, it must be done by the

farmers themselves. And if, in this brief talk, I have said anything that has impressed even one of you with the idea that the men of the present are only holding the soil in trust to pass on to future generations, and that it is among our highest duties to prevent all the wash possible, my talk has been fully worth while.

# Good Road Development in Tennessee*

Wilbur A. Nelson.

The first settlers that moved into Middle Tennessee had a hard and rough journey to reach the promised land of which they had heard. At that time it lacked, as did practically all of this new country of ours, any means of communication, other than the streams and rivers. Thus in the settling of Nashville, the journey from the Watauga Settlement in northeastern Tennessee was made by journeying down the Tennessee River to the Ohio, and then poling up the Cumberland and back into Middle Tennessee, a journey at that time of several months' duration.

Later the Indian trails were used by the settlers in their intercourse with one another, and in going back to their homes in Virginia. These trails gradually became more and more traveled and many of them were later followed by the old stage roads. The names of the most famous of these roads still linger with us, although their exact routes are known to only a few. The old Natchez Trace was probably the best known, but one often hears other names such as the Nicojack Trail, *etc.* These were Tennessee's first roads, rough and rocky, but supplying the needs of that generation. It is interesting to take the map of the State and locate the many small post-offices, the names of which end in "stand", showing that they were located on the old stage roads. Connecting these you can in a rough way plot out the routes that the old stage roads followed. Even before Tennessee became a state, much interest was manifested by the settlers, and considering the time, a large amount of road improvement was carried on. The first turnpike that the State authorized to be built was in 1801, and was in Carter County, one of the most northeastern counties of Tennessee.

The great development in road building that has characterized the Appalachian states, among which is Tennessee, in the last few years, is not new development, but accelerated development following a period of retarded development. In 1836, eight years after the first railroad was built in the United States (the Baltimore and Ohio), Tennessee passed a law requiring the State to take one-third of the stock in every railroad and turnpike company organized in the State. The development was instan-

*This paper was delivered before the Southern Appalachian Good Roads Association, at its annual meeting on November 20, 21, 1912, in Atlanta, Ga.

taneous and great, and in that year turnpikes were authorized with a combined capital of $560,000. But even this did not satisfy the lawmakers, and in 1838, the law was amended so that the State was required to take one-half the stock in every railroad or turnpike chartered. Up to 1839, the State had issued $899,580 internal revenue bonds. This shows an approximate expenditure of two million dollars in road construction. In 1841, the State had subscribed $1,477,166 to turnpike construction in Middle Tennessee, $87,500 in West Tennessee. While the figures for East Tennessee are not available, they were probably about a half million dollars. From these figures a conservative estimate would show that over five million dollars was spent between the years 1836 and 1841 in building turnpikes. At that time the population of the State was only 829,210, which is roughly about a third of the present population.

Thus we see that seventy years ago, Tennessee was expending money at nearly the same rate per capita that it has in the last few years for the building of good roads. These laws were repealed after several years, but not until the object for which they were passed had been accomplished. Tennessee was constructing at this early period a system of turnpikes and railroads that would have been the equal of any in the country, if the Civil War had not arrested their development.

The citizens of Tennessee were well blessed with a farsighted vision, and saw that without a way of getting their products to a market their development would be slow and uncertain. This was the cause of the impetus given to good roads from the 30's to the 60's. In East Tennessee the development was first directed towards railroads, as was right, and was to have been followed by a system of pikes to act as feeders. Middle Tennessee, being better situated, in having an outlet through Cumberland River, devoted most of its energies to turnpike building. It was at this period that most of the turnpikes around Nashville were built. The Civil War stopped this work. Just after the war, the Brownlow Administration started a good roads movement, but it was stopped when this government was overthrown in 1870, and since then very little has been accomplished in road building, until a few years ago.

At the beginning of Governor Hooper's administration in 1911, a movement for good roads in general, and especially for a state highway from Memphis to Bristol was inaugurated. The following extract is taken from his speech made at Knoxville on October 16, 1912, in which the work that has already been accomplished on this state highway is set forth as follows:

"Between Memphis and Nashville, 26 miles have been and are being built in Shelby County, six in Fayette, the entire distance across Haywood, the few miles necessary in Madison, $40,000 worth in Humphreys,

and some work has been done in Carroll. Much educational work has been done in the other counties.

"Between Bristol and Nashville, 1,592 miles of the preliminary survey have been completed, and 94.5 miles of the location surveyed. Contracts have been let on 76.5 miles, and 19.7 miles is being done by force account. Cannon County has appropriated $5.000 bonds; Warren, $11,800; White, $90,000; Cumberland, $40,000; Roane, $20,000; Loudon, $40,000; Washington, $60,000; Carter, $60,000, and Sullivan and Hamblen a sufficient part of a general bond issue. There are already 181 miles of macadamized road on this eastern end of the route.

"This insures the completion of the highway. The building of this road, and the agitation incident thereto, have stimulated good road building all over the State, as well as building continuations of the highway both in Mississippi and Virginia."

From a financial point there are three methods of building roads in Tennessee; first, by the building of private turnpikes, which, in many cases have been afterward purchased by the counties; second, the use of county prisoners, supplemented by additional labor and machinery; and third, the issuance of bonds by the counties. The first method, was the one used before the Civil War. The second method prevails in the counties containing the large cities. The last method is the one most extensively employed today. To issue bonds, the county must first be authorized to do so by the Legislature, and afterwards must secure a favorable vote from the people of the county. In 1891, the number of counties authorized to issue bonds was one; in 1911, the number was 33.

The following counties are those that have issued bonds for road construction:*

| | |
|---|---|
| Anderson | $ 300,000 |
| Bradley | 200,000 |
| Blount | 300,000 |
| Campbell | 200,000 |
| Carter | 60,000 |
| Cocke | 200,000 |
| Cumberland | 40,000 |
| Grainger | 200,000 |
| Greene | 250,000 |
| Hamblen | 300,000 |
| Hamilton | 665,000 |
| Hawkins | 200,000 |
| Hickman | 24,500 |
| Jefferson | 395,000 |
| Madison | 500,000 |

*Figures for this table were given by C. C. Gilbert, Nashville Board of Trade.

| | |
|---|---|
| Marion | 265,000 |
| McMinn | 225,000 |
| Monroe | 300,000 |
| Montgomery | 450,000 |
| Morgan | 85,000 |
| Lauderdale | 25,000 |
| Loudon | 100,000 |
| Putnam | 250,000 |
| Roane | 100,000 |
| Robertson | 450,000 |
| Sevier | 160,000 |
| Smith | 30,000 |
| Sumner | 200,000 |
| Sullivan | 300,000 |
| Union | 50,000 |
| Warren | 150,000 |
| Washington | 60,000 |
| White | 200,000 |
| Total | $7,234,500 |

Tennessee is well blessed in every section with excellent material for good roads. For West Tennessee, are available the extensive deposits of chert and gravel that occur in that section. In Middle Tennessee, limestone or chert covers the whole area, except the Cumberland Plateau, which is composed of sandstone and shales. In East Tennessee good road building limestone is as abundant as in the middle section of the State. It is supplemented by large deposits of fine-grained chert in certain places. Thus we see that all sections of the State are easily and cheaply supplied with good road materials that are being widely used at the present time.

## Publications of Geological Survey of Tennessee Issued.

The following publications have been issued by the present Survey, and will be sent on request *when accompanied by the necessary postage.* To make it possible for libraries to complete their sets, and for persons having real need for any of the volumes to obtain the earlier ones at small cost, 500 copies of each report are reserved for sale, at the cost of printing; the receipts from the sales being turned into the State Treasury.

Gaps in the series of numbers are of reports still in preparation:

**Bulletin No.** 1—Geological Work in Tennessee.

A. The establishment, purpose, object and methods of the State Geological Survey; by Geo. H. Ashley, 33 pages, issued July, 1910, postage, 2 cents.

B. Bibliography of Tennessee Geology and Related Subjects; by Elizabeth Cockrill, 119 pages; postage, 3 cents.

**Bulletin No.** 2—Preliminary Papers on the Mineral Resources of Tennessee, by Geo. H. Ashley and others.

A. Outline Introduction to the Mineral Resources of Tennessee, by Geo. H. Ashley, issued September 10, 1910; 65 pages; postage, 2 cents.

D. The Marbles of East Tennessee, by C. H. Gordon; issued May, 1911; 33 pages; postage, 2 cents.

E. Oil Development in Tennessee, by M. J. Munn; issued January, 1911; 46 pages; postage, 2 cents.

G. The Zinc Deposits of Tennessee, by S. W. Osgood; issued October, 1910; 16 pages; postage, 1 cent.

**Bulletin No.** 3—Drainage Reclamation in Tennessee; 74 pages; issued July, 1910; postage, 3 cents.

A. Drainage Problems in Tennessee, by Geo. H. Ashley; pages 1-15; postage, 1 cent.

B. Drainage of Rivers in Gibson County, Tennessee, by A. E. Morgan and S. H. McCrory; pages 17-43; postage, 1 cent.

C. The Drainage Law of Tennessee; pages 45-74; postage, 1 cent.

**Bulletin No.** 4—Administrative Report of the State Geologist, 1910; issued March, 1911; postage, 2 cents.

**Bulletin No.** 5—Clays of West Tennessee, by Wilbur A. Nelson; issued April, 1911; postage, 4 cents.

**Bulletin No.** 9—Economic Geology of the Dayton-Pikeville Region, by W. C Phalen, for sale only, price 15 cents.

**Bulletin No. 10**—Studies of the Forests of Tennessee.

A. An Investigation of the Forest Conditions in Tennessee, by R. Clifford Hall; issued April, 1911; 56 pages; postage 3 cents.

B. Chestnut in Tennessee, by W. W. Ashe, issued December, 1911; postage, 2 cents.

**Bulletin No. 13**—A Brief Summary of the Resources of Tennessee, by Geo. H. Ashley; issued May, 1911; 40 pages; postage, 2 cents.

**Bulletin No. 14**—The Zinc Deposits of Northeastern Tennessee, by A. H. Purdue; issued September, 1912; 69 pages; 30 illustrations, postage, 3 cents a number.

"**The Resources of Tennessee**—A monthly magazine, devoted to the description, conservation and development of the State's resources. Postage, 2 cents a number.

PRINCIPAL PAPERS.

Vol. I. No. 1—The utilization of the small water powers in Tennessee, by J. A. Switzer and Geo. H. Ashley.

No. 2.—The Camden chert—an ideal road material, by Geo. H. Ashley.
The Fernvale iron ore deposit of Davidson County, by Wilbur A. Nelson.
Cement materials in Tennessee, by C. H. Gordon.

No. 3—The gold field of Coker Creek, by Geo. H. Ashley.

No. 4—Coal resources of Dayton-Pikeville area, by W. C. Phalen.

No. 5—Economic aspects of the smoke nuisance, by J. A. Switzer.
Watauga Power Company's hydro-electric development, by Francis R. Weller.
The coal fields of Tennessee, by Geo. H. Ashley.

No. 6—Bauxite Mining in Tennessee, by Geo. H. Ashley.
A New Manganese Deposit in Tennessee, by Wilbur A. Nelson.
Road Improvement in Tennessee, by Geo. H. Ashley.

Vol. II. No. 1—The Utilization of the Navigable Rivers of Tennessee, by Geo. H. Ashley.
Dust Explosions in Mines, by Geo. H. Ashley.
The Rejuvenation of Wornout Soil Without Artificial Fertilizers, by Geo. H. Ashley.
Tennessee to Have Another Great Water Power, by George Byrne.
Manufacture of Sulphuric Acid in Tennessee in 1911, by Wilbur A. Nelson.

No. 2—The Ocoee River Power Development, by J. A. Switzer.
Exploration for Natural Gas and Oil at Memphis, Tenn., by M. J. Munn.

No. 3—The Power Development at Hale's Bar, by J. A. Switzer,
Notes on Lead in Tennessee, by Wilbur A. Nelson.

No. 4—The Tennessee Academy of Science.
The Preliminary Consideration of Water Power Projects, by J. A. Switzer.
Lignite and Lignitic Clay in West Tennessee, by Wilbur A. Nelson.

No. 5—The Growth of Our Knowledge of Tennessee Geology, L. C. Glenn.

No. 6—On the Impounding of Waters to Prevent Floods, by A. H. Purdue.
Drainage Problems of Wolf, Hatchie, and South Fork of Forked Deer Rivers, in West Tennessee, by L. L. Hidinger and Arthur E. Morgan.
The Waste From Hillside Wash, by A. H. Purdue.

No. 7—Where May Oil and Gas Be Found in Tennessee? By Geo. H. Ashley.
Spring Creek Oil Field, by M. J. Munn.

No. 8—The Monteagle Wonder Cave, by Wilbur A. Nelson.
Cave Marble (Cave Onyx) in Tennessee, by C. H. Gordon.

No. 9—The Valley and Mountain Iron Ores of East Tennessee, by Royal P. Jarvis.

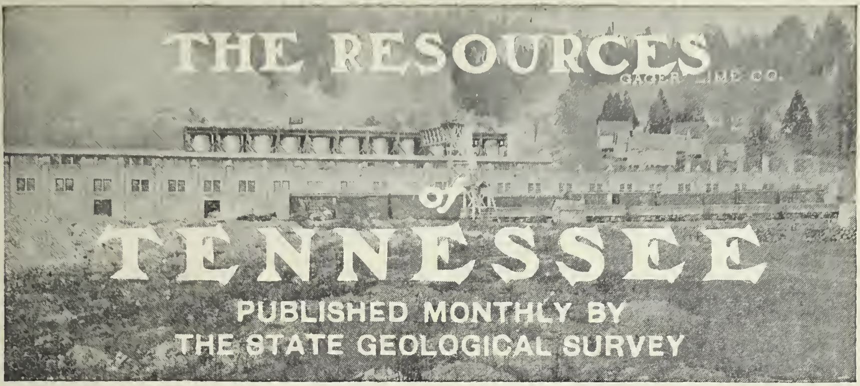
No. 10—The Iron Industry of Lawrence and Wayne Counties, by A. H. Purdue.
Some Building Sands of Tennessee, by Wilbur A. Nelson.

No. 11—Tests on the Clays of Henry County, by F. A. Kirkpatrick. Introduction, by Wilbur A. Nelson.
Barite Deposits in the Sweetwater District, by Herbert B. Henegar.

No. 12—The Soils and Agricultural Resources of Robertson County, by Reese F. Rogers.
The Iron Ore Deposits in the Tuckahoe District, by C. H. Gordon and R. P. Jarvis.

## NOTE

It was the original plan of the Survey to publish the material on *The Iron Ores of Tennessee,* as Bulletin 2-C; but from a change of plans, it was published as the leading article in Volume II, No. 9 of *The Resources of Tennessee,* under the title, *The Valley and Mountain Iron Ores of East Tennessee.* This number of *The Resources of Tennessee* is herewith inserted, in order to complete the publications as originally outlined.




VOL. 2. NO. 9 NASHVILLE SEPTEMBER, 1912

View of part of the Tellico basin with the mountains in the background, on the sides of which iron ore occurs.

## IN THIS ISSUE



WILLIAMS PRINTING COMPANY, NASHVILLE

# THE RESOURCES OF TENNESSEE

*A Magazine Devoted to the Description, Conservation and Development of the Resources of Tennessee*

PUBLISHED MONTHLY AT NASHVILLE BY

THE GEOLOGICAL SURVEY OF TENNESSEE

A. H. PURDUE, State Geologist

WILBUR A. NELSON, Assistant Geologist

Entered as second-class matter July 14, 1911, at the Postoffice at Nashville, Tenn., under the Act of July 16, 1894.

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# The Valley and Mountain Iron Ores of East Tennessee.

By ROYAL P. JARVIS.

## INTRODUCTION.

The region covered by the present review includes the counties of Johnson, Carter, Greene, Cocke, Sevier, Blount, Monroe, and Polk, the eight border counties between Tennessee and North Carolina. These contain within their borders the great range of mountains, known by various local names as the Great Smokies, the Unakas, the Blue Ridge, *etc.* Usually there are several parallel ridges making up the system. To the northwest of the range is the great valley of the Tennessee. The Unakas, or Great Smokies, are but a part of the system which stretches continuously from New York to Alabama. The area included within Tennessee may be said roughly to cover a strip extending northeast-southwest for 200 miles, with a width of 10 to 15 miles, or an approximate area of 2,000 to 3,000 square miles. Within this strip are included both the "Valley" and the "Mountain" ores of East Tennessee.

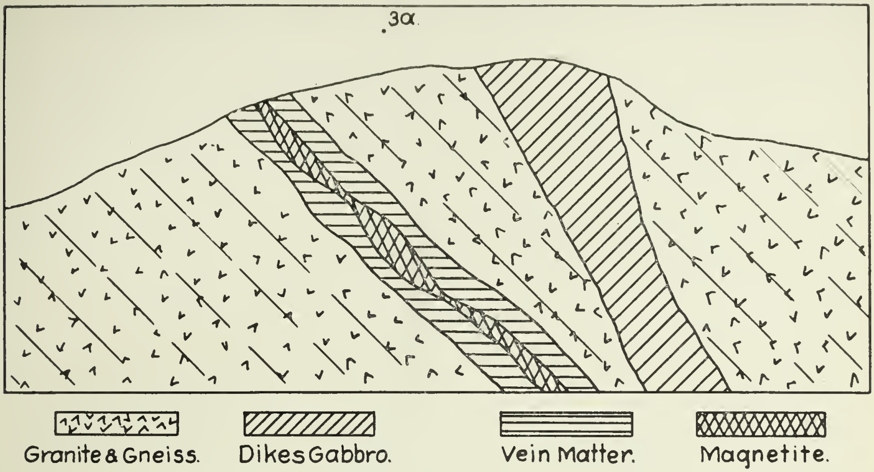
## GEOLOGY.

The geology of the Appalachians has been the subject of numerous reports, and was one of the first regions to receive the attention of the early geologists of this country. The elaborate State reports of the Pennsylvania Survey, the New York State Survey, the reports of Safford and Killebrew in Tennessee, together with the more recent detailed reports and folios of the U. S. Geological Survey, and the reports of the State Geologists of Georgia, Alabama, Virginia and Maryland have served to make our knowledge of the general geology of the region quite complete.

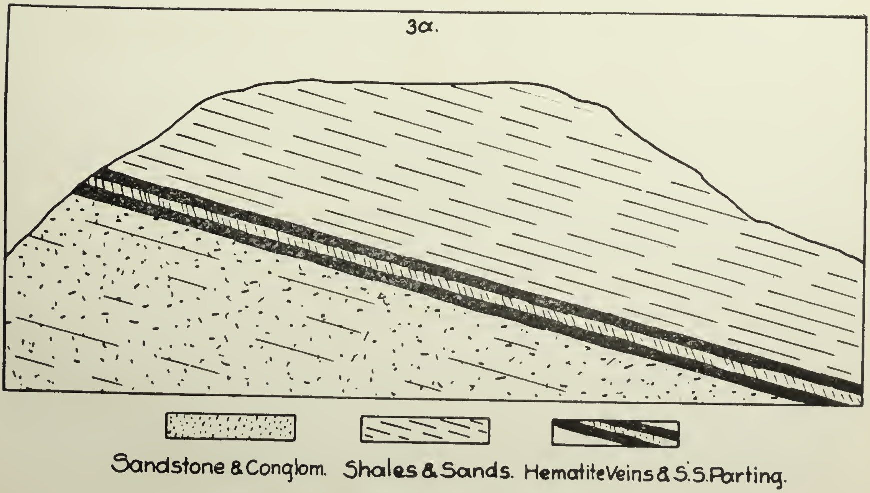
A generalized geologic section within Tennessee, extending northwest

from the North Carolina boundary, a distance of 20 miles, is made up of Cambrian and Ordovician rocks, with pre-Cambrian and metamorphic rocks constituting the underlying basal members. For the most part the series consists chiefly of sedimentary rocks—sandstones, conglomerates, shales, slates and limestones. These different members, which are not absolutely uniform in thickness and character, have received the name of some locality where they are typically exposed. In the early reports, those writers who were familiar with the Pennsylvania State reports, called the whole series of sedimentaries the Pottsdam; Safford considered this Pottsdam group of Tennessee (Geology of Tennessee, 1869, p. 192) as made up of three great subdivisions: 1. The Ocoee conglomerates and slates; 2, the Chilhowee sandstone; and 3, the Knox group of shales, dolomites and limestones. Recent work of the U. S. Geological Survey has placed the Knox group in both the Cambrian and Ordovician systems. For practical purposes, however, the more minute subdivisions of the later is not a very important matter. Following the nomenclature of the later surveys, the principal members constituting the geologic series up into the Silurian are as follows:

| | | | | | |
|---|---|---|---|---|---|
| Silurian | Rockwood formation | 400-700 | | | Vari-colored shales and calcareous sandstones with one or more iron beds. |
| | Clinch sandstone | 0-500 | | | Massive white sandstone. |
| | Bays sandstone | 50-1300 | | | Massive and shaly red sandstone. |
| Ordovician | Sevier shale | 850-2000 | Tellico sandstone | 2-900 | Calcareous shales and limestones. |
| | | | Athens shale | 800-1600 | |
| | Moccasin limestone | 450-500 | | | Red, blue and gray massive and shaly limestone. |
| | Chickamauga limestone | 0-900 | | | Massive and shaly limestones and marble. |
| | Knox dolomite | 3000-4400 | | | Light blue to white magnesian limestones with chert. |
| Cambrian | Connasauga shale | 1100-6000 | Nolichucky shale | 50-750 | Red to yellow calcareous shales. |
| | Honaker limestone | 100-2200 | Maryville limestone | 0-950 | Massive blue and gray limestone. |
| | | | Rogersville shale | 180-220 | |
| | | | Rutledge limestone | 0-450 | |
| | Watauga limestone or Russell formation or Rome formation. | 500-1600 | Rome formation | 750-950 | Purple to brown and yellow shales and sandy shales. |
| | | | Beaver limestone | 300 | |
| | | | Apison shale | 900 | |
| | Shady limestone | 750-1000 | | | Gray and white limestones, usually dolomitic with some marble. |
| | Hesse or Erwin quartzite | 500-1200 | | | Massive white quartzite and sandstone. |
| | Hampton shale | 600-800 | Murray shale | 200-400 | Sandy shales and quartz. |
| | | | Nebo quartzite | 200-1700 | Massive white quartz. |
| | | | Nichols slate | 400-2100 | Blue to gray shales and slates with sandstone. |
| | Unicoi formation | 1500-2500 | Cochran conglomerate | 1200-2500 | Massive quartz conglomerates and quartz. Vari-colored slates, with conglomerates and calcareous sandstone. |
| | | | Hiwassee conglomerate or Sandsuck shale | 300-900 | |
| | | | Snowbird | 350-5000 | Gray and white quartzites, sandstones, and shaly beds with sills of amygdaloid. |




CLASS 1- MAGNETITE




CLASS 2- BEDDED DEPOSITS.

Since the division of the Cambrian formations is based almost entirely upon lithologic characters, which admittedly affords a basis for only tentative divisions, the same formations have been given two or more names in places where faults are numerous and of great throw. In many sections where sedimentary rocks occur, measurements of their thickness running into the thousands of feet have been given when they are in reality much less.

Owing to the harder and less soluble nature of the conglomerates and quartzites, they are found capping the highest mountains and ridges, while the softer and more readily soluble calcareous shales, shaly limestones and limestones form the more rounded hills and knobs.

The formations genetically related to the iron ores of this region are the granites, and gneiss and dikes of gabbro, and related basic eruptive rocks in the southwestern part of Carter County; the Cochran conglomerate or some of its equivalents; the Erwin quartzite and its equivalents, with the overlying Shady limestone; the Watauga shale; Knox dolomite; and the Rockwood formation, the local name for the Clinton iron ore horizon.

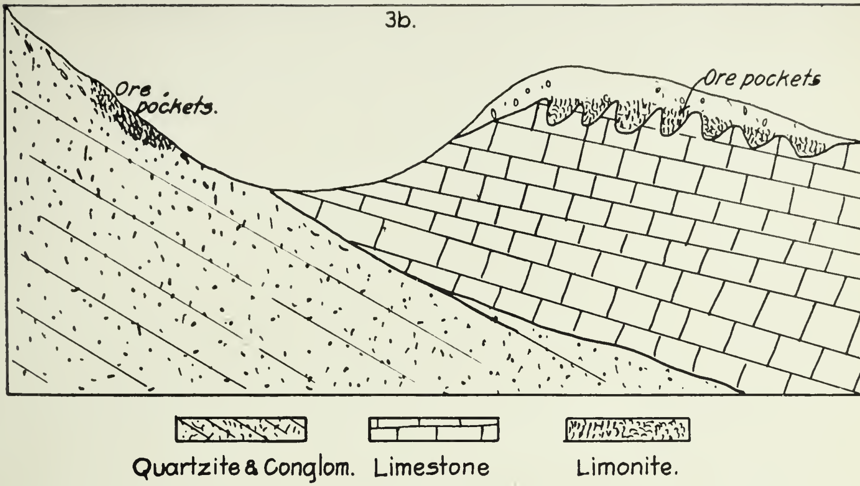
### ECONOMIC GEOLOGY.

*Kinds of ore.*—The iron ore deposits of this region may be classified as follows:

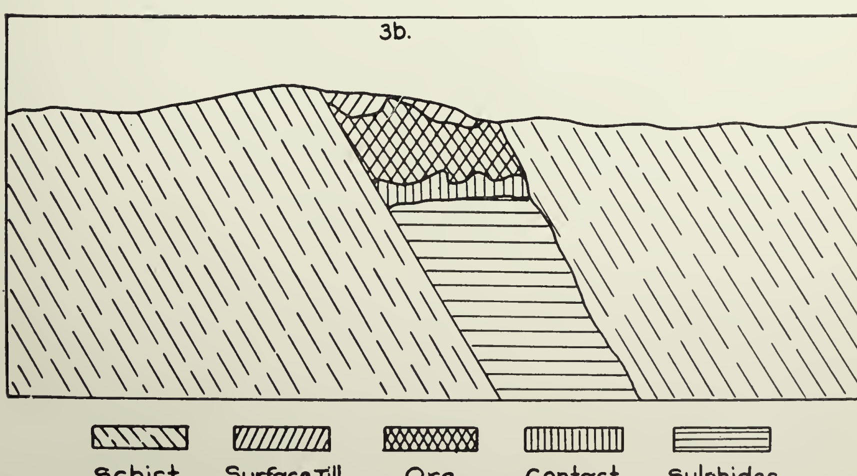
1. Deposits of magnetite ($Fe_3O_4$), containing, when pure, 72% of metallic iron. These deposits occur in the Cranberry granite, a fine and coarse grained biotite granite and granite-gneiss. These deposits within the Tennessee area have never been extensively developed, although a number of openings have been made along the course of this deposit. These are undoubtedly on a continuation of the Cranberry deposit of North Carolina, and are traceable for a distance of about nine miles within Tennessee.

2. Bedded deposits in the Cochran conglomerate or its equivalent. Such deposits occur in Bumpus Cove, where some work was done in the early days. They are of very low grade, however.

3. Replacements deposits of limonite ($2Fe_3O_4$. $3H_2O$). Theoretically this carries 59.92% iron. Similar hydrated oxides of iron, such as goethite (62.93% iron); or turgite (66.29% iron), occur in faults of brecciated zones in the quartzites; or as small irregular deposits parallel with the bedding planes in some of the shale members, particularly the Watauga shale. These deposits often show up very well at the surface, but when depth is attained, or when traced for any considerable distance along their strike, they gradually fade out into barren quartzite or shale. This class of deposits is generally known as the "Mountain Ore," since




CLASS 4-VALLEY ORES.




CLASS 6 - GOSSAN ORES

it occurs high up on the mountains. In the early days of the iron industry in this region, it supplied a large part of the ore reduced.

4. Residual deposits of limonite, or related hydrated oxides of iron, found in the clays resulting from the solution of the limestone or dolomite. Such deposits occur overlying the Shady limestone and the Knox dolomite. The ore is usually found disseminated in the clays and sands as nodules, ranging in size from masses weighing several tons to grains as fine as a mustard seed. This class of deposits has proved the most important. They are confined to "pockets," which vary extremely in size and shape, as well as in the amount or proportion of iron. In mining it, it is necessary to separate the adhering clay and other barren material from the ore by washing and hand picking or jigging. In some cases it has been noted that the ore deposits are more or less continuous and form a solid bed overlying the limestone (Shady), but not resting directly upon it, as is true with the Bumpus Cove deposits.

5. Bedded deposits in the Rockwood formation. These outcrop on the northwest side of Chilhowee Mountain. They have not received much attention, nor have they been developed to any extent within the area under consideration, although of great importance in the region lying immediately west and north, in Campbell, Anderson, Roane and Meigs counties.

6. Gossan deposits of limonite are found overlying the primary sulphides of iron and copper in the Ducktown district. These ores have been derived entirely from pyrite and pyrrhotite, the commonly occurring sulphides of iron, through the slow, natural process of oxidation by atmospheric agencies. They show great irregularity as regards both depth and thickness. They are low in phosphorous, but may contain considerable sulphur and copper. The ores have been mined in open cuts, from which the shipping ore was selected more or less by hand.

*Origin of the ores.*—In the genesis of so many classes of deposits, it is evident that no one theory can account for all. Much has been said concerning the second and fifth classes, those bedded deposits which are conformable with the inclosing rocks. Their development within this region has been insufficient to determine whether there is a progressive diminution in the iron percentage as depth is attained. This has usually been found to be the case elsewhere, and when the permanent water level is reached, or the bed is protected by a heavy overburden, the ores are generally of lower grade.

The genesis of the first class, the magnetites, is undoubtedly closely related to the history and formation of the gabbro dikes, the related igneous rocks, and the inclosing granites. The magnetites occur in lenses conformable with the planes of schistosity, which resemble bedding planes.

These lenses vary in thickness from less than a foot to 30 feet or more, and are from five to ten times as long as thick. The mineral, magnetite, is distributed irregularly through the mass making up the lens, and the ore in general can not be classed as high grade in the crude. To render it of economic value it must be concentrated. At Cranberry, North Carolina, this is effected on magnetic separators. The minerals associated with magnetite are hornblende, pyroxene and epidote, and in miner amounts, feldspar and quartz. Owing to the large amount of hornblende, pyroxene and epidote, which are tough and hard minerals, the ores are hard to crush preparatory to dressing or magnetic concentration. It has been held by Keith (Cranberry Folio, No. 90) that the ore body "is not due to original segregation from an igneous granite, but is entirely of a secondary nature". It may have replaced a preëxisting mass of rock by solution and substitution, or it may have been deposited from solution in open spaces in the inclosing rock". He considers the latter very unlikely. Since the magnetite lense takes the shape of the mass of intruded basis igneous rock, which occurs in the immediate locality, as noted in the openings made on the Campbell property, it is therefore altogether likely that the magnetite lenses merely represent a segregation from an ultra-basic ingneous rock, intruded into the granites. In some cases, secondary reactions may have taken place due to pressure, heat and circulating waters. Thus while the origin of the magnetite is not due to an original segregation from the inclosing granite, nevertheless the ore as found, is due to the segregation from an extremely basic eruptive rock.

The geneses of the third and fourth classes doubtless have much in common. It has been held by some writers (H. M. Chance, *Trans. American Institute Mining Engineers,* Vol. 39, p. 522), that these surface deposits of limonite represent the oxidized portions of great masses of iron sulphides, and that these sulphide deposits will be found beneath. While the writer can not speak for regions outside of Tennessee, nothing that he has thus far examined within the State would warrant such conclusions. It is quite possible that the mineral now in the form of limonite was originally derived from adjacent rocks, shales and quartzites, which are known frequently to carry disseminated iron pyrite; but the iron originally in the form of pyrite has been oxidized, leached out and deposited where now found, in the fault zones above mentioned. The ore now found disseminated in the clays overlying the Shady and other limestones, has doubtless been derived chiefly from the small amount of iron in the overlying limestone.

To illustrate how rapidly small amounts of iron in a stratum of rock will develop into large tonnages of ore, let it be assumed (1), that the Shady limestone will average 1 per cent of iron (many samples will yield

this amount); (2), that all the iron contained in the limestone goes into the deposit, from solution and reconcentration; (3), that the resulting tonnage is based upon a washed ore containing 50% of iron; (4), that the specific gravity of the limestone is 2.70, and therefore one cubic foot weighs 168 pounds. Approximately, one cubic foot of unaltered limestone will contain 1.68 pounds of metallic iron, or 3.36 pounds of 50 per cent iron ore. An acre of such limestone one foot thick will contain 43,560 times this much (43,560 square feet in an acre), or 73,180 pounds of metallic iron, which equals 146,360 pounds (almost 75 short tons) of 50% iron ore. If 100 feet of such a limestone is dissolved away over an acre, it will yield no less than 14,636,000 pounds, or 7,318 short tons. of 50% iron ore. Since in many cases at least no less than 500 to 700 feet of limestone has been removed by solution, the amount of iron ore yielded under assumed conditions is really astonishing.

Of course in nature the above assumed conditions are never fulfilled, chiefly because much of the iron is carried away either in solution, or combined with other minerals and removed by erosion. This simple case will suffice to show that any rock carrying even very small quantities of a given mineral is quite sufficient to account for very much more ore than we find. The difficulty is not to find a source, but to determine the laws that govern the solution, migration and precipitation of the minerals themselves. Terms and names have been coined to express these facts, but the exact and definite effects of such forces as osmosis, mass action, surface tension and adhesion between minute particles, together with varying effects of temperature, pressure, and an unlimited amount of time for these forces to act, renders the problem a most difficult one. However, our knowledge of the genesis of ore deposits must, in the future, be sought chiefly in a study of the laws of physical chemistry.

### HISTORICAL SKETCH OF IRON PRODUCTION.

The beginning of the iron industry in Tennessee was practically coincident with the early settlement of the State. A number of factors contributed to this result, among which may be noted: The long distance of the settlement from commercial centers, and particularly the seaboard towns, and the consequent high price of iron in any commercial form; the wide distribution, and ease with which the iron ore deposits of the State could be worked; the cheap and abundant supply of water power, charcoal, and cheap labor. The result was, that every county of East Tennessee, and almost every cove and valley had its forge, bloomery or blast furnace. In the early days, bar iron was one of the recognized mediums of exchange. J. M. Safford (*Geology of Tennessee*, 1869, p. 464). gives a list of the various blast furnaces and forges, with the production

for the year 1854, seven years before the beginning of the Civil War. Nine blast furnaces are listed, of which five were then in blast, yielding about 1,800 tons of pig iron. For the same period, 29 establishments, having 51 forges, producing about 500 tons of bar iron and 700 tons of blooms, are listed. While figures of production for years preceding this are not at hand, it is safe to say that these figures were not exceeded, if in fact they were closely approached. Following the war, the industry was completely paralyzed, and in the counties of Greene, Sevier and Blount it has never been revived. In recent years, in the region under consideration, the counties of Polk, Unicoi, Johnson, Washington, Monroe, Carter and Cocke, in the order named, have been the chief producers. The following table, condensed from the annual reports of the Chief Mine Inspector of Tennessee, gives the value and production in long tons for the years from 1903 to 1910 inclusive. Practically all the ore is limonite, or brown hematite. This table includes all the producing counties in this section:

*Table Showing Production of Iron Ores in Tennessee, 1903-1911*

| Year | Cocke County | | Washington County | | Polk County | | Johnson County | | Unicoi County | | Carter County | | Monroe County | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Long tons | Total value | Long tons | Total value | Long tons | Total value | Long tons | Total value | Long tons | Total value | Long tons | Total value | Long tons | Total value |
| 1903 | 2,000 | $2,500 | ...... | ........ | 115,799 | $139,290 | ....... | ....... | ...... | ....... | ...... | ...... | ...... | ...... |
| 1904 | 487 | 608 | 2,002 | $ 3,500 | 41,883 | 36,392 | ....... | ....... | ...... | ....... | ...... | ...... | ...... | ...... |
| 1905 | 500 | 900 | 40,907 | 102,267 | 92,734 | 78,705 | ....... | ....... | ...... | ....... | ...... | ...... | ...... | ...... |
| 1906 | 250 | 450 | 44,717 | 80,491 | 78,714 | 118,070 | $39,699 | $69,474 | 8,195 | $14,752 | ...... | ...... | ...... | ...... |
| 1907 | ..... | ...... | 24,015 | 36,021 | 74,644 | 78,144 | 59,185 | 88,477 | 34,711 | 52,066 | 1,557 | $6,935 | 6,100 | $8,113 |
| 1908 | ..... | ...... | 15,007 | 15,007 | 36,141 | 37,127 | 50,639 | 68,208 | 6,218 | 6,218 | ...... | ...... | ...... | ...... |
| 1909 | ..... | ...... | 2,632 | 3,948 | ....... | ........ | 47,602 | 72,324 | 5,250 | 7,875 | ...... | ...... | 2,490 | 3,350 |
| 1910 | ..... | ...... | ...... | ........ | ....... | ........ | 6,867 | 13,995 | ...... | ....... | ...... | ...... | ...... | ...... |
| 1911* | ..... | ...... | ...... | ........ | ....... | ........ | ....... | ....... | ...... | ....... | ...... | ...... | ...... | ...... |

*No Production.

Compiled from Reports of the Chief Mine Inspector of Tennessee.

The following table, condensed from the reports of the Chief Mine Inspector of Tennessee, and the Mineral Resources of the U. S. Geological Survey, shows the total production of Tennessee iron ores since 1889, in long tons:

| Year | Tons of red hematite | Tons of brown hematite | Carbonate | Total, according to the U. S. G. S. | Total, according to the State reports |
|---|---|---|---|---|---|
| 1889 .......... | ....... | ....... | ..... | 473,294 | ....... |
| 1890 .......... | ....... | ....... | ..... | 465,695 | ....... |
| 1891 .......... | ....... | ....... | ..... | 543,923 | ....... |
| 1892 .......... | ....... | ....... | ..... | 406,578 | 406,478 |
| 1893 .......... | ....... | ....... | ..... | 372,996 | 372,996 |
| 1894 .......... | ....... | ....... | ..... | 292,831 | 292,831 |
| 1895 .......... | 257,502 | 255,583 | 6,711 | 519,796 | 519,796 |
| 1896 .......... | 207,502 | 326,932 | 800 | 535,484 | 535,484 |
| 1897 .......... | 260,550 | 343,947 | ..... | 604,497 | 604,497 |
| 1898 .......... | 284,616 | 308,611 | ..... | 593,227 | 617,579 |
| 1899 .......... | 298,704 | 333,342 | ..... | 632,346 | 667,149 |
| 1900 .......... | 283,784 | 310,387 | ..... | 594,171 | 699,724 |
| 1901 .......... | 314,949 | 474,545 | ..... | 789,494 | 620,458 |
| 1902 .......... | 370,643 | 503,899 | ..... | 874,542 | 628,870 |
| 1903 .......... | 371,189 | 481,515 | ..... | 852,704 | 724,264 |
| 1904 .......... | 309,419 | 191,563 | ..... | 500,982 | 539,820 |
| 1905 .......... | 272,996 | 461,774 | ..... | 774,770 | 730,981 |
| 1906 .......... | 279,971 | 590,763 | ..... | 870,734 | 879,059 |
| 1907 .......... | 269,182 | 544,508 | ..... | 813,690 | 817,767 |
| 1908 .......... | 226,038 | 409,305 | ..... | 635,343 | 588,988 |
| 1909 .......... | 298,818 | 358,977 | ..... | 657,795 | 648,825 |
| 1910 .......... | 301,838 | 430,409 | ..... | 732,247 | 674,693 |

This table shows that in a period of nearly 25 years the total iron ore production has varied from something over a quarter of a million tons to slightly over three-quarters of a million tons per annum. The periods of greatest production naturally closely coincide with the prosperous years, and the periods of depression follow closely upon intervals of commercial stagnation or suspense. These figures of production, as compared with 1910, in such states as Minnesota with its nearly thirty-two millions of tons or Michigan with over thirteen millions of tons are quite small. For the last ten years Tennessee's rank as a producer of iron ores among the states has ranged from the sixth to the ninth, and the percentage of total production from 1.2 to 2 per cent.

### TRANSPORTATION FACILITIES AND MARKETS.

In the early reports of Safford and Killebrew great stress was laid upon the difficulty of transportation, and the distance of the ore deposits from the railways and other centers. Since these reports were written the number of miles of railway in the region in question has increased

many fold, so that at present, even in spite of the difficulties and cost of railway building and a rough and mountainous district, the whole region is readily accessible. The lack of transportation facilities can no longer be advanced as an excuse for the slow development of the East Tennessee iron deposits. Cheap and abundant supplies of excellent fuel, together with excellent limestone for fluxing purposes, are close at hand. The climate is healthful, the soil generally fertile and labor abundant at reasonable prices. The deposits are near the largest markets of the country, and in the midst of a rapidly growing manufacturing region. These things ought to be sufficient to stimulate the growth of the iron industry in this region. All other questions aside, it seems to the writer that the one factor as yet undetermined in the production of iron in East Tennessee is that of iron ore in sufficient quantities and grade to make it possible to compete with other states.

## DESCRIPTION OF SOME OF THE PRINCIPAL LOCALITIES BY COUNTIES.

While the following report is confessedly not a complete one owing to lack of time to cover all the territory, and other causes, it is submitted in the hope that it may be of some service to those who are at present interested in the development of the iron deposits of this district, and to prospective investors. The writer has made an effort to visit in person all mines, openings and banks, the description of which is given. The description of the Tellico region, Monroe County, is by Dr. C. H. Gordon. Much of that region has been covered by the writer in the interests of private parties, and analyses have been made of several samples selected by Dr. Gordon. It is safe to say that these deposits all fall within the classes made in the foregoing pages, chiefly classes 3 and 4.

### BLOUNT COUNTY.

The iron deposits lying within Blount County may be included under classes 3, 4 and 5. In the early days production was mainly from the residual deposits in the Knox dolomite. More recently some promising prospects have been opened up on the northwest side of Chilhowee Mountain which the writer considers as the Rockwood formation. This belt can be traced from Walland, southward beyond Montvale Springs. Several openings have been made on the property of the Chilhowee Mountain Mining Company, about two miles south and west of Walland. Mr. J. F. Brittain, of Maryville, who is general manager, states that a few cars of ore were shipped in 1907. One of the cuts shows two beds, the lowest having a thickness of 26 inches, with a sandy parting 46 inches

thick above it, and on top of this a 40-inch seam. The beds dip 35 degrees nearly southeast and strike N. 50 degrees E., parallel with Chilhowee Mountain. The ore is hematite, in part altered to limonite near the surface. Its physical and chemical characters are almost identical with the so-called "soft ores" of the Rockwood district. An analysis of a piece of the ore taken off one of the dumps gave, in an air dried sample iron, 46%; silica, 21.0%; lime, trace. Northeast of Walland a similar deposit was opened a number of years ago, and it is probable that this same horizon is more or less continuous along Chilhowee Mountain in the direction of Sevierville for a distance of 10 to 12 miles. The present exposures are in the vicinity of extensive faults, and what the effect of these will be upon further development of the veins can not be definitely stated.

In the coves lying between the outlying mass of Chilhowee Mountain and the Lower Cambrian quartzites to the south and east, pockets of limonite have been found over the limestones. In the early days a forge was operated near the head of Miller's Cove, about four miles southwest of Walland. Other pocket deposits of limonite are known to exist in Cades Cove, 10 miles south of Walland.

Near Amarine Gap, four miles southwest of Walland, small pockets of manganese have been found in the Murray shale. The ore occurs interbedded with the shales and in thin veins from two to six inches thick. An analysis of a sample taken from a small pile of ore sorted out on the dump of one of the openings gave 52.4% of manganese. These deposits appear to be too small and erratic to be considered of much economic importance.

On the property of John White and D. C. Williamson, two miles east of Walland, near the foot of Mt. Nebo (Chilhowee Mountain) small amounts of limonite are found here and there, scattered through the soil, which has probably been derived from the weathering of the Sevier shales. They are not of sufficient extent or depth to be of importance.

Five miles south of Maryville a pocket of brown ore in the residual clays from the Knox dolomite was operated in a small way a number of years ago, and five miles to the northeast of the same town is another similar deposit.

### CARTER COUNTY.

The geology and character of the iron ore deposits of Carter County show greater variety than that of any other county in East Tennessee. The northwestern part of the county shows the same stratigraphy as Johnson County on the northeast and Washington and Greene counties on the southwest. A geologic section of the mountains and ridges bordering the valley on the northwest shows a great series of bedded sandstones,

quartzites, and shales, with the Shady and Honaker limestones of Cambrian age forming the floors of the valleys and coves. Thus, Stony Creek valley in the northeastern part of the county, and Shady valley in the adjoining county of Johnson, occupy troughs in the Shady limestone, while Bumpus Cove, which lies in the contiguous counties of Washington and Unicoi to the southwest, has been eroded in the same limestone. Associated with these rocks are found iron deposits of the 2d, 3d and 4th classes.

In the extreme southeastern part of the county igneous rocks, granites, and gneiss abound, and associated with these rocks are the magnetites, the type described under class 1.

In recent years the production of the county has been practically nothing, but in the early history of the State the deposits in Stony Creek valley, as well as the magnetites on Doe River at Hampton Forge, were important. As late as the 70's, the deposits on Stony Creek were operated, and the ore smelted in blast furnaces at Carter. The two principal districts in this county therefore are the Stony Creek valley region, in the northeastern part, and the Doe River and Hampton Forge region in the southeastern part of the county.

*Stony Creek.*—As noted above, this valley occupies a trough in the Shady limestone, hemmed in on three sides by rough ridges, made up of the underlying quartzites and shales. The ores have come from deposits of the 3d and 4th classes. The early forges and blast furnaces derived most of their supply from the "mountain ores," principally from deposits on Holston Mountain. The Knoxville Car Wheel Company operated a small charcoal furnace near Carter, and their ores were derived chiefly from "banks" along Hodge branch, on the south side of the valley. These were residual ores from the Shady limestone, and belong to class 3. The pig iron made from this ore was considered very desirable, but owing to the distance from railways at the time this furnace was operated, and cheaper sources elsewhere, the furnaces were finally closed, and are now completely dismantled.

The latest attempt to develop the iron deposits of Stony Creek, was made by the Virginia Iron, Coal & Coke Company in 1906-07 at the Hodge ore banks. This company owns large areas of ore land in this locality, and a considerable sum was expended at this bank to open and equip it. A washery, side tracks and steam tram-lines were constructed, and preparations made for a heavy production, but the records show that only some 1,600 tons were produced. The washery is now completely dismantled, and the tracks torn up. An inspection of the ground over which they worked gave little evidence of any considerable amount of

ore. Some pits have been sunk along some of the edges of the banks, but show little ore.

Considerable pit prospecting has also been done in the vicinity of Winner, on both Holston and Iron mountains. In both cases the search appears to have been carried on in areas off the limestones, either in the underlying shales (Murray slate) or quartzite (Hesse), with discouraging results. Some ore was found, but no large bodies. This ore has evidently been derived from the limestone, but the limestone has been completely removed, leaving the iron scattered through the wash from the adjacent shales and quartzites.

*Magnetites on tributaries of Doe River.*—In the extreme southeastern part of Carter County, on Shell, Heaton, Roaring and Tiger creeks, tributaries of Doe River, are to be found a number of occurrences of magnetite. The part lying within the boundaries of Carter County is within the belt of magnetites which extends, more or less continuously, a distance of about 15 miles westerly from Cranberry to Magnetic City, North Carolina, of which the middle 10 miles lies within the boundaries of Tennessee.

The lands supposed to cover the outcrop of this ore are owned by a number of interests. Among the largest may be noted the Tennessee Coal, Iron & Railroad Company, the Crab Orchard Iron Company, J. C. Campbell, of Johnson City, and others. The most extensive openings made on the deposit within Carter County are located at the old Hampton Forge, two miles south of Roane Mountain station on the East Tennessee and Western North Carolina Railway. The land which is said to belong to the Crab Orchard Iron Company was under lease, in 1899, to Mr. George L. Carter, who is shipping considerable ore at this time. The vein has been developed by open cuts, the most extensive of which is on the east side, and about 100 feet higher than the bed of the river. At this point it has a strike nearly east-west, and dips at a high angle to the south. The ore deposit appears to be made up of two portions, a lower seam or lens, 12 to 15 feet thick, above this a lean parting of 8 to 12 feet thick, and on top a rich seam six to eight feet thick; but these dimensions seem to vary within short distances. Much of the ore appears to be rather lean. The deepest point examined was about 25 feet below the surface. The character of ore appears to be identical with that of the Cranberry mines. On the west side of Doe River, about 600 feet west of this opening, another cut has been made on this vein. Here the total width of the vein is 20 feet, but with the exception of a streak about two feet thick, the deposit is low grade. Some ore is said to have been shipped from this opening in 1899. At the time this deposit was worked, a branch line connected the station and Roane Mountain, but the heavy floods of 1902 washed it out completely, and it has never been rebuilt. Ores from this

deposit were drawn on to supply the forges located at a point about where Doe River cuts across the vein. The iron made from these ores was noted for its strength and superior qualities.

The land of Mr. J. C. Campbell, located near the head of Roaring and George creeks, about three miles south of Crabtree station and on the East Tennessee and Western North Carolina Railway, has recently been prospected by open cuts. The vein, where exposed in the largest cut, has a strike nearly east-west, and dips 45 degrees south. A section of the vein, as shown in this cut, was as follows: On the bottom there was 4.5 feet of fair grade ore, above this 12 to 14 feet of granite gneiss, and on top of the gneiss 2.5 feet of ore similar to that at the bottom. Both ore and gneiss were much decomposed. Prospecting at this point has been sufficient to show that even in such short distances as 20 to 30 feet the thickness and continuity of the veins, or lenses varies much. About 400 feet east of the main cut, a tunnel had been driven in to catch what was supposed to be the continuation of the vein. The tunnel was said to be 90 feet long. Judging from material on the dump, the vein was not encountered. Again, to the west of the main cut, some 700 feet, another cut had been driven, on a line with the strike of the vein. No ore was found, but it served to uncover a mass of dark, basic eruptive rock, probably a gabbro. Still another cut had been made to find the vein about 3,000 feet east of the main cut. Here a good deal of work had been done, but resulted in nothing more than exposing a large mass (probably a dike) of igneous rock, composed chiefly of augite, and related to the gabbros. Numerous other openings have been made along the course of the vein, but owing to lack of time they could not be examined.

The genesis of these magnetite deposits is undoubtedly closely bound up with the basic igneous rocks of the district. The generally disseminated character of the ores, the variation of the pay streak in thickness and length, and their close association with dikes of extremely basic eruptive rock, show conclusively that the ores themselves are nothing more than segregations from an ultra-basic magma.

While development upon the magnetite area in Tennessee has not been extensive, enough has been done to show their close relationship with the Cranberry deposits. The Cranberry ores are not particularly high in iron, but owing to the very small amounts of sulphur, phosphorous, copper and titanium, pig iron made from these ores commands a premium. Magnetic concentration will have to be applied to similar ores mined in Tennessee. Owing to the rapid variation in thickness, both along the strike and dip, the quantities are always uncertain; and while the belt within which magnetic ores occur is fairly well defined, it does not follow that the deposit is a continuous one, or that where present prospecting has un-

covered an outcrop of ore, such openings always indicate commercial deposits.

## COCKE COUNTY.

The principal iron ore areas of this county are centered around the two little stations of Del Rio and Wolf Creek, respectively 12 and 17 miles east of Newport, the county seat. They are situated on the French Broad River and the Nashville division of the Southern Railway. Nearly 40,000 acres of mineral land are owned by the Tennessee Coal, Iron and Railroad Company in this and adjacent counties.

*Hurr mine.*—This mine has produced most of the ore from Cocke County in recent years. It is located three miles northwest of Del Rio, near the northeast extremity of Stone Mountain. Work is said to have been carried on here intermittingly from 1890 to 1906. The deposits, which occur in the Watauga shale, have been opened in a number of places and follow a vein which has a strike N. 50 degrees E. The deepest working is said to be in a field shaft, which stopped in the ore at a depth of 40 feet. No well defined outcrop was visible at the surface. Much of the ore appears to have been taken from the residual sandy clays, and a product averaging 45% iron, and 0.1 per cent phosphorous was obtained by hand sorting. The selected ore was hauled by tramway and wagon to the railway switch.

On a tract of land adjoining the Hurr property on the northeast, some excellent manganese ore has been found. The manganese deposits occur in the Watauga shale as pockets or lenses roughly parallel with the bedding planes of the shale. The largest and only important pocket found was 70 feet long, 30 feet deep, and 20 feet wide. This was completely worked out, and considerable effort expended to find other deposits, but without success.

Two miles south of Del Rio on the property of Mr. R. M. James, a little prospecting has recently been done. These deposits likewise occur in the Watauga shales. One small vein of limonite interbedded with the shales was traceable for several hundred feet on the surface. On the surface the vein averaged from two to four feet wide, varying much in the quality of the ore, while in the cut at a depth of about 16 feet the vein was 18 inches thick, and lean. An examination in the vicinity of this cut, where the surface had been removed, showed a number of small veins of limonite interbedded with the shales, all less than eight inches thick.

In the residual deposits derived from these shales, considerable "wash ore" occurs, but no efforts have been made to develop it. Owing to the thin covering of such wash, and the very irregular distribution of the ore, together with the presence of a large amount of loose, shaly sandstone,

all high above the streams, not much importance is to be attached to it. Some manganese occurs associated with the small limonite veins, as a part of the vein filling, forming a distinct band from one to five inches thick.

There are a number of outcrops and openings on the property of Joseph Huff and others located on the north of French Broad River following the axis of the Meadow Mountains. The major valleys between the ridges are floored with the Shady limestone, but usually at a slight elevation above the creek beds, the shales and shaly sandstones begin. These, together with the more massive quartzites and conglomerates, constitute most of the mountain masses. The limestone usually occupies a nearly horizontal position, but close to the contact with the shales is tilted and broken, showing that the positions now occupied are the result of an overthrust fault. This has brought the underlying shales above the limestone. Associated with the shales, and along these faults are a number of outcrops of limonite. These deposits occur, apparently, as bedded members with the shales and shaly sandstones. At one place on Long Creek cuts had been made across the vein for 50 feet, and a cut eight feet high showed some very good ore. But an examination for several hundred feet along what should be the strike of the deposit did not show the ore. All these deposits fall into class 3. It is said that four carloads of ore, averaging 48% iron, were shipped from this location to Embreeville in 1909. When the furnace was operated, at Haysville, Greene County, this ore was hauled there by wagon. Scattered over the surface for a distance of about 1,000 feet are masses of limonite. Much of this class of ore was probably gathered in the early days and hauled away.

Adjoining this tract on the east and northeast the Tennessee Coal, Iron and Railroad Company have large holdings. They were not examined, but as they occur in the same belt they naturally fall into the same class as the above.

*Wolf Creek.*—Practically the entire area between Del Rio and Wolf Creek, five miles east, and beyond to the North Carolina line, is held by the Tennessee Coal, Iron and Railroad Company. In the early 80's it is said this company surveyed a line from the present station of Wolf Creek, on the French Broad River, up Wolf Creek a distance of three miles to what was considered a promising locality. At that time some prospecting was done, but the railroad was never constructed, and no further work was done until 1909, when Mr. H. M. LaFollette, who had secured a lease on both the Tennessee Coal, Iron and Railroad Co.'s land and the land adjacent, belonging to other parties, commenced prospecting. This work was carried on in the vicinity of the old bank, which appears to be one of those deposits of limonite in the shales, class 3. The vein ranges from

four to eight feet in width, and is traceable 700 feet, in a course S. 75 degrees W., with a steep south dip. The ore was silicious and lean. There were a number of prospect pits sunk over an area of about 20 acres. A few of the dumps showed some ore, but many of them were blanks. To the southwest of this area from 1,000 to 2,000 feet, another area underlaid by the quartzite was prospected by pits, but with negative results. This same belt of iron ore continues on to Paint Rock, North Carolina. North of the French Broad River the same belt which was traced along the Meadow Mountains is contiguous with that lying in Greene County.

### GREENE COUNTY.

The general features of the iron deposits of Greene County are analogous to those of Cocke County. The belt is traceable along the entire eastern end of the county, where it skirts the high ridges; and along the margins of the small interior coves or valleys, lying between the outstanding ridges on the northwest and the main mountain mass on the southeast. That portion lying within the southwestern part of the county is a part of the same field that was traced in Cocke County.

Within the territory drained by Cove Creek are a number of prospects and surface showings. These occur on the outlying ridge known as Meadow Mountain, on the main ridge forming the watershed between Cove Creek and its tributaries, and on the French Broad River on the south. Large acreages are held by the Tennessee Coal, Iron and Railroad Company, and James S. Park, Esq., *et al.*, of Greeneville. A number of these outcrops were visited, and all those deposits may be referred to class 3, and residual deposits in the clays, embraced under class 4.

*Mills bank.*—This is located near the head of Cove Creek on the south side, 150-250 feet above the bed of the creek. Deposits of limonite in shale, and sandy shale have been opened in several places, of which one shows a deposit 12 to 14 feet wide and dipping steeply to the south. A sample taken across the vein gave the following from the air-dried sample: Iron, 42.5%; silica, 24.8%; lime, trace. This vein can be traced along its strike about 400 feet, but pinches down to only a foot or two, and the ores becomes leaner. On the opposite side of the cove, on the south slope of Meadow Mountain, a small opening has been made and a small vein of limonite from one to twenty feet wide has been uncovered. This was interbedded with shales and clay. A sample of this ore gave the following analysis: Iron, 51.8%; silica, 8.5%; lime, trace.

*Lamb bank.*—This is located on the south side of Cove Creek, about 500 feet above the valley, where a shallow cut 60 feet long has been made on an outcropping of limonite, interbedded with sandy shales. The cut was badly caved, work having been done about 40 years ago. The ex-

posed edges showed mainly iron stained sandstone, with an irregular vein having a maximum width of 12 feet. A sample across this vein gave the following analysis: Iron, 44.2% ; silica, 17.3% ; lime, trace. The enriched vein was not traceable for any length. The deposit, which appears to be a surface concentration, with its greatest width at the surface, is of only limited length and depth. In the vicinity of the Lamb bank other small veins have been opened in the shale, but they are too small and irregular to be of economic importance. A sample of such ore gave the following analysis: Iron, 35.0% ; silica, 34.6%.

*Varner bank.*—This is one of the old-time openings close to the wagon road, where it crosses the divide from Cove Creek to Paint Rock. Some development has been done by shaft, which is now caved in. The surface is covered rather deeply with wash, and there are very slight indications of iron.

Deposits similar in most respects to those described above are found on the northwest side of Meadow Mountain. The property is controlled by Mr. James H. Park, Greeneville, Tenn., and the outcrop visited consists of a large pocket of limonite, which occurs near the bottom of a hollow interbedded with quartzites. In this locality a zone between 20 and 30 feet has been mineralized. The vein dips steeply to the south. The mineralization across the vein is not uniform, and the widest and best portions appeared to be near the bottom of the hollow. The vein was traceable several hundred feet along the strike, the iron gradually disappearing, and the deposit passing into a barren mass of fractured quartzite. Analyses of the richer parts gave the following: Iron, 42.0% ; silica, 26.4% ; lime, trace. Other deposits of this kind are found scattered over this mountain, both on the north and south slopes. Such deposits can all be referred to class 3.

*Haysville mine.*—The East Tennessee and Greene County Iron Company had two blast furnaces in operation in the vicinity of what was Haysville in the early 70's. They were known as the "upper" and "lower" furnaces respectively. The lower furnace received its ore supply mainly from the banks just described, while the upper furnace drew most of its supply from a bank in the immediate vicinity. The upper furnace is about two miles northeast of the lower one, which was the oldest and smallest.

The openings in the vicinity of the upper furnace are the largest ever worked in the county. These deposits occur in some faults close to the contact zone between the Shady limestone and adjacent shales. In some of the cuts, remnants of what were probably the veins mined for the ore, were visible. The largest one was three to four feet thick. Other smaller and irregular seams were scattered here and there through a decomposed yellow shale. It is said a shaft was sunk on one of the largest veins, but

no evidence of it remains. This deposit belongs to class 3. The charcoal iron made here was considered of fine quality. It was hauled 12 miles by wagon to Greeneville, then, and still, the nearest railway station. The furnaces were closed during the panic of 1873, and have never resumed operations.

*Green Ridge deposits.* — These deposits, located near the corner of Greene, Washington and Unicoi counties, were the scene of early operations, the ores having supplied several forges in the vicinity. The open cuts examined were badly caved, and no solid outcrops were visible. The deposits belong to class 3. Fragments of limonite can be found widely scattered over the surface here and there, and on the strength of this a little recent prospecting has been done in several places, without success.

## JOHNSON COUNTY.

Johnson County occupies the extreme northeast corner of the State. The geology of this county is similar to that of Carter County, as it relates to the sedimentary rocks in which the iron ores occur. Mining operations have been confined chiefly to two localities, one along Roane Creek and its tributaries on Dry Run Mountain, Doe Mountain and Forge Mountain, and the other in Shady Valley, in the northwestern part of the county. The deposits occurring in this county fall into classes 3 and 4.

*History.*—Before the war Johnson County was noted for its iron production. In 1854 there were 15 forges with 26 fires in operation. For many years after the war production was at a standstill. In 1906 the Virginia Iron, Coal and Coke Company began operating on Roane Creek, and continued operation till 1910. In the early 80's a small charcoal furnace known as Butler furnace, was operated for a short time on Furnace Creek, three miles north of Mountain City. Owing to the distance from the markets at that time, the furnace was closed, and since has been completely dismantled. The Virginia Iron, Coal and Coke Company have been the principal operators in this county in recent years, and at present own large areas of mineral land. Other operators and owners in the district, all of Tennessee, are Mr. A. D. Reynolds, Bristol; Knight & Maxwell, Butler; Empire Lumber and Mining Company, Shady Valley; Forge Mountain Mining Company, Mountain City; J. S. Jenkins, Mountain City; Iron Mountain Mining Company, the mineral rights of which are said to have reverted to the original owner; and Mr. W. H. Wilson, Neva, Tennessee.

*Doe Mountain mines.*—The Doe Mountain mines of the Virginia Iron, Coal and Coke Company, located near Maymead, on the southeastern slopes of Doe Mountain, consist of a number of open cuts in pockets of limonite, distributed through residual clays and washed from the adja-

cent shales and limestones. Steam-shovel methods of mining are not well adapted to these deposits, and the cost of getting the dirt to the washery down in the valley is considerable. All the material mined has to be either hauled in tram cars, a distance of three to four miles, or hydrauliced and sluiced about half a mile to the washery.

The ores have been derived from the erosion of pocket deposits made in the quartzites, and similar deposits in the adjacent shales. In several instances work has been done upon the solid ore in place. While these mass deposits are often of considerable width, in one instance nearly 40 feet, the values are irregular, and the ore shades off quickly into ferrugenous sandstone and shale, so that where this class of ore is mined most of it must be hand picked in order to bring it up to the shipping grade. The bank located near the top of what is locally known as Flint Knob was a hydraulic proposition, and one of the richest opened. This deposit is underlaid by the Shady limestone. The ores on Flint Knob were mined by hydraulic giants, and carried in sluices to the washery below. Water for hydraulicing was supplied by pumps located in the valley, pumping against a head of about 400 feet.

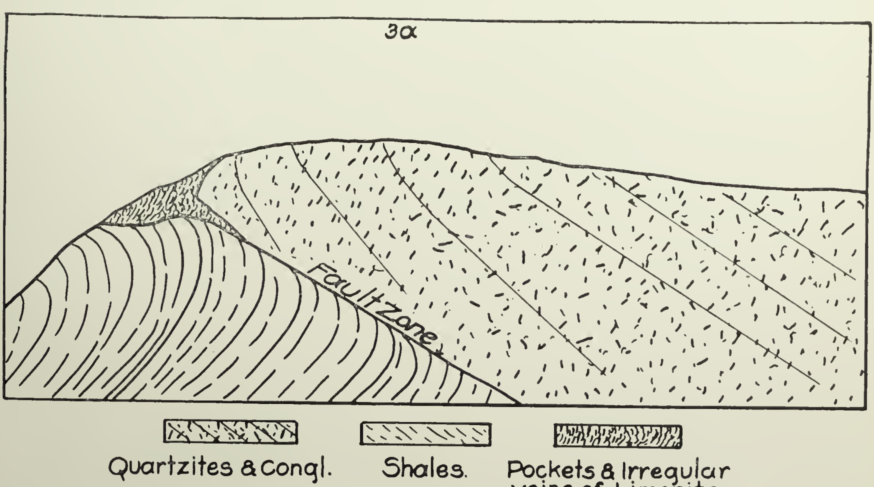
The washery located at Maymead is equipped with four pairs of logs. The scheme of treatment is that usually followed. The ore from the tram cars is dumped at the lower end of a pair of logs, if delivered in cars, or sluiced directly into the log-troughs if delivered from hydraulic operations. The overflow and the water from the logs go to waste, the heads to a de-watering screen, and the over size to picking and covering belts. From these the coarse waste is picked out and delivered to waste-bins, and the clean ore is discharged from the picking belts to ore bins. The same company have another washery at Shouns, two miles south of Mountain City, where a bank of "wash ore" similar to that on Flint Knob has been successfully worked. This is known as the Donnelly bank.

Two miles south of Neva, near Baker's Gap, considerable prospecting has been done by pits, shafts and tunnels. The deposits of limonite occur in shale, close to the Shady limestone, and belong to class 3. The tunnels and shafts were inaccessible, but the search for ore in considerable quantities appears to have been unsuccessful. It is said that the company that did this work is no longer in existence.

*Forge Mountain mines.*—The mines of the Forge Mountain Mining Company are located on the western side of Forge Mountain, near Mountain City. The mine is known locally as the Rist bank. This is situated near the crest of Forge Mountain, between 400 and 500 feet above the valley. Since this is one of the best examples of the third class of limonite deposits, and has been abundantly proved, a somewhat detailed description of it will be given. There are two principal openings on the

north and south slopes of a small gap. The northern opening shows a mass of limonite filling a fault zone between quartzite and shale. The quartzite forms the hanging-wall, and the shale the foot-wall. The outcrop is traceable for about 200 feet, when it passes into a broken mass of quartzite. The iron fades out on the north end, and the south end is buried beneath wash. Since this work was done, the cuts and shafts have become filled, and it is uncertain how deep exploration was carried, but probably not more than 40 feet below the surface. But before even this depth was reached it appears that the ore had practically disappeared, and its place taken by ferruginous shales and sandstone. The opening on the south side of the gap appeared to have been made entirely in the quartzite, and somewhat higher than the north cut. The deposit proved to be nothing more than a thin coating of ore lying over the quartzite, with stringers and fingers penetrating the quartzite to a depth of six to eight feet. The pocket had been stripped for a width of 75 feet, and for a slightly greater length. Some prospect pits put down several hundred feet south of this cut along its strike showed no ore.

A large sum of money was expended on this property to make a producing mine of it. Ore bins were erected on a spur of the Virginia and Southwestern Railway, near Mountain City, to receive the ore. A narrow gauge railway between three and four miles in length was built to connect the mine with railway. Inclined planes and short tramways were constructed to connect the mines with the narrow gauge line, and other things were done, only to find that the ore was not there. The following sketch illustrates the relations at this mine, and serves also to show a representative type of this very common class of limonite deposit found throughout the region, i. e., class 3:




CLASS 3-MOUNTAIN ORES.

*Butler bank.* — The Butler bank, located about three miles north of Mountain City, on Furnace Creek, suppiied a small charcoal furnace nearby, which was operated for a short time in the early 80's. The banks are located in shales, and near quartzites. The outcrops show pockets of limonite 30 feet wide in places, with values irregularly distributed through the mass. The ores are similar to those noted at the Rist bank, Maymead, and elsewhere, and belongs to class 3.

*Jenkins property.*—On the J. S. Jenkins property, one mile northwest of Mountain City, a little work has been done on two small pockets of limonite interbedded with Watauga shale. Numerous outcrops similar to this can be found along the valley of the Little Doe.

*Shady Valley.*—An effort was made in 1905 by the Empire Lumber and Mining Company to develop a tract of ore near the upper, or southern end, of the valley. An examination of the bank from which the ore was mined showed a mass of stiff yellow clay, overlaid by 10 to 15 feet of sandy clay, mixed with boulders. Scattered through the stiff clay, which is probably derived from the Shady limestone, were little veinlets of limonite, none more than two inches thick. A thoroughly modern washery, equipped with logs and jigs, was erected to handle the dirt. Work was carried on here for about two years, as a result of which about six carloads of ore were shipped. The washery has been completely dismantled. Other openings showing limonite have been made in Shady Valley, but they were not visited.

### MONROE COUNTY.

The iron ores of this county occur in the vicinity of Tellico Plains, a pear-shaped basin or cove in the southwestern part of Monroe County, with its longest axis extending from northeast to southwest. It is about ten miles long and from three to three and one-half miles wide. The southwestern end of the valley is drained toward the southwest by Conasauga Creek, while the remaining and larger part of the valley is drained northward by the Tellico River. This stream breaks through the hills on the southeast into the valley near the middle, and flows northward, cutting through the red hills of the Tellico formation, which bounds the plains on the west and north.

The town of Tellico Plains is situated at the east side of the valley near where the Tellico River breaks through the ridge of crystalline conglomerates and slates into the limestone-floored valley. It is the terminus of the Tellico Plains branch of the Louisville and Nashville Railroad, which connects with the main line at Englewood Station.

The valley of Tellico Plains is bounded on the southeast by a series of ridges which connect toward the northeast and south with the Unaka

range, a few miles distant. The first of the ridges is called the Mocking Crow Mountain, succeeded on the southeast by the Tellico Mountain and others. Where these have not been denuded of their timber, they are clothed with a fine growth of chestnut oak, black oak and hickory.

*Geology.*—The plains are underlaid by the Knox dolomite, the strata of which have been folded into a broad low arch with the axis coincident with that of the major axis of the valley. A fault follows the eastern boundary of the valley, whereby the crystalline conglomerates, quartzite and slates of Safford's Ocoee have been brought up against the Knox dolomite. This fault, which hades toward the southeast, crosses the Tellico River just below the bridge. The crystalline rocks form an interesting belt extending from the northeast to the southwest, their harder formations standing out in series of ridges parallel with the general strike of the rocks. They dip at a high angle toward the southeast.

*Iron ore deposits.*—The principal deposits of iron ore, which is all of the brown or limonitic type, occur in pockets along the slopes of Mocking Crow Mountain southwestward from where the Tellico River crosses the ridge. On the east slope of the ridge are a number of pockets in the sands derived from the decomposition of the quartzites and other crystalline rocks.

One-fourth mile south of the river on the west side of Laurel Creek is the Latrobe bank. A small opening has been made here showing concretionary ore in a highly ferruginous sand. The bank lies on the east slope of the ridge about 60 feet above the valley bottom. The deposit is apparently the result of the disintegration of the quartzite formation which constitutes this portion of the ridge. In places only is the ore sufficiently concentrated apparently to constitute a workable ore. The extent of the deposit could not be determined.

About a mile southwest of the Latrobe bank is the Queen bank. Here an open cut ten feet deep extends 150 feet along the valley side. The ore occurs in concretionary masses in residual sands. The degree of concentration varies, in places consisting only of outcropping ledges of ferruginous sandstone. Some ore was taken from this bank and used in the furnace once operated at the mouth of Laurel Creek. Opposite the bank, across the valley toward the east, a small creek—Fall Branch—drops 210 feet into the valley, offering favorable conditions for hydraulic methods of mining.

Southwest of Queen bank a short distance is Red Hill bank. Here ore is exposed in places along the slope, but no work has been done, and nothing is known of the extent of the deposit. The relations of the deposit here are much the same as in the banks described.

On the south side of the Madisonville pike, about one-half or three-fourths mile south of Red Hill bank, is Round Knob. The ore crops out in the road and extends up the slope of the knob. The ore seen is low grade and occurs in clays in the form of irregular masses and concretions.

*Hale or Bill Coppinger bank.*—This bank is located on the west side of the ridge about a mile south of town. It is the only place in the district where mining of any importance has been done. A large amount of ore was taken out of this bank to supply the furnace and bloomeries in operation before the war. An opening several hundred feet long and 150 feet wide has been made. The ore occurs in nodules and irregular masses and as shot ore in a matrix of white and buff clays derived from the Knox dolomite. The deposit lies close to the fault, which brings the dolomite against the quartzite on the southeast. Test pits sunk along the strike of the ore northeast show no deposit beyond the former workings. Very little ore is in sight due in part probably to falling in of the walls of the pit.

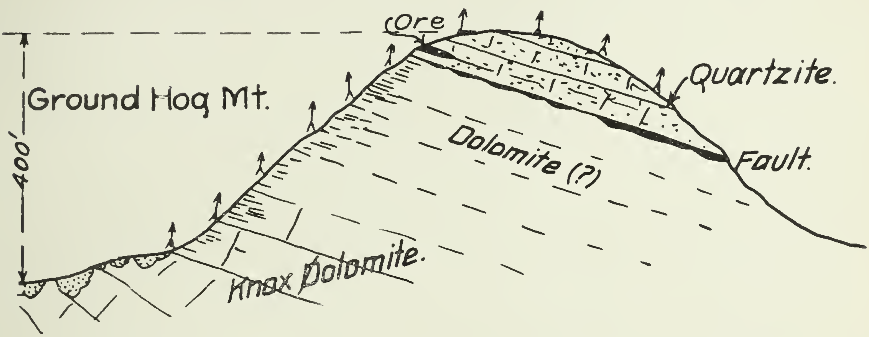
Southwest from the Coppinger bank fragments of ore occur at intervals along the side of the mountain, and in places small pits have been sunk, but no well defined body of ore has been exposed between the Coppinger and Donnelly bank, at the southwest end of Peaky Top. A hundred yards southwest of the Coppinger bank some ore has been taken out of a pit located along side an outcrop of the quartzite.

*Donnelly bank.*—As noted above, this bank is situated on the southwest slope of a peak of Mocking Crow Mountain, called Peaky Top. It is about a mile southwest of the Coppinger bank, and about 200 feet below the top of the mountain. The mountain is capped by quartzite which crops out a short distance above the ore bank. The ore is in clays, evidently derived from the dolomite, as at the Coppinger bank. Two masses of ore appear at the surface separated by 150 feet of clay. Very little prospecting has been done, but surface indications point to a considerable amount of ore. The large outcropping masses are of low grade.

*Ground Hog Mountain bank.*—Two miles northwest of Peaky Top, and three miles in a straight line southwest of Tellico Plains, is a local elevation 400 feet high called Ground Hog Mountain. Ore is exposed in a number of shallow pits along the crest of this mountain for a distance of one-fourth of a mile. The mountain is composed of a capping of quartzite resting upon Knox dolomite. The forested slopes of the mountain are covered by a thick mantle of residual material derived in large part from the dolomite.

The ore occurs in the quartzite, which has a dip of about 25 degrees toward the southeast. In one place near the south end of the mountain a small lens of ore occurs within the quartzite. One hundred yards north-

east of this a small pit shows a layer of ore 8 to 10 inches thick just under the quartzite and underlaid by clay. Northeast of this, at intervals, other similar exposures occur, but sufficient work has not been done on any of these to define the extent of the ore. The relations of the ore here are evidently the same as at the Coppinger, the deposits being associated with the fault, which has thrust the quartzite over the dolomite.




Southward along the west slope of Mocking Crow Mountain, and along the east slope of Starr Mountain, ore occurs in scattered fragments in the clays derived from the dolomite. On Starr Mountain these outcrops occur just below the Nebo sandstone, which constitutes the main mass of the mountain. This sandstone appears here as overthrust upon the dolomite the same as the quartzite on the east side of the valley, suggesting the correlation of the quartzite with the Nebo sandstone. In a few cases small amounts of ore occur at lower levels away from the vicinity of the fault, as at Kelby's place, six miles south of Jalapa, where it appears unmistakably as a replacement of the dolomite. A ledge that appears as iron ore outcropping in the road was seen to grade quickly into unaltered dolomite. In many cases the texture of the ore suggests its derivation by replacement of the dolomite, though generally this is the result of concentration of the iron in the undisturbed clays derived from the dolomite.

*Analyses of ores from Tellico Plains.**

| Locality | Iron per cent | Silica per cent | Lime (CaO) per cent |
|---|---|---|---|
| Ground Hog Mt. ore.................... | 37.9 | 28.27 | Trace |
| Donnelly bank ore..................... | 40.2 | 27.5 | 0 |
| Latrobe bank ore...................... | 43.1 | 23.2 | Trace |

*Samples collected by Dr. C. H. Gordon.

### POLK COUNTY.

The iron ores from this county have come entirely from the oxidized gossan deposits of copper ore in the Ducktown district. The principal producing mines have been the Burra Burra, Eureka and Isabella, and all belong to class 6. The gossan iron deposits of Polk County were large and steady producers up to 1908. The Ducktown copper deposits occur in veins, have approximately the same dip and strike as the inclosing rock, which is a mica schist. The veins have a strike of N. 20 to 25 degrees E., and dip usually to the southeast. The widths and depths to which the primary iron sulphides have been changed to oxides varies between wide limits. On the Burra Burra mine, oxide iron ores have been mined to a depth of 60 to 90 feet. In most places, however, it is less than this, and does not appear uniform.

### SEVIER COUNTY.

Sevier County, which lies between Blount County on the southwest and Cocke County on the northeast, partakes of the geologic, topographic and economic features of the other border counties.

*Pigeon Forge.*—In the early history of the iron industry in the State Sevier County had two small centers of production—one in the vicinity of Pigeon Forge, six miles south of Sevierville, and the other near the head of Dunn's Creek, 15 miles east of this town. The ore supply for the forges at Pigeon Forge was obtained chiefly from small banks located along what is now known as the Ridge road, between the Forge and Sevierville. These deposits belong to class 4. The old pits were badly caved, and the dumps overgrown with forest, but judging from their present size, the quantity of ore moved was very small. In 1910 a party of Knoxville capitalists undertook to prospect this area, and a number of prospect pits were sunk over an area of perhaps 15 to 20 acres. Some of the pits indicated ore, but the quantities were generally small and irregular. Some of the ore treated at Pigeon Forge was supplied from Ware Cove. Around the borders of this cove, close to the limestone and shale contacts, are small pockets of limonite in residual clays, belonging to class 4. Higher up on the sides of the mountains forming the southern boundary of the cove, several small pockets in the quartzites, belonging to class 3, have been found.

*Dunn's Creek.*—On Dunn's Creek a small charcoal blast furnace was in operation some 75 years ago, and it is said that it was finally closed down because the manganese in the ore became so high that they had not only difficulty in smelting it, but the resulting pig could not be used.

An examination of the old diggings from which the ore was obtained showed that the deposit occupied a fault zone between the limestone on the hanging-wall, and shale on the foot-wall, and consisted of limonite, with which was associated more or less oxide of manganese. On the surface the deposit has a width of 10 to 12 feet, and little manganese; but at depths of 15 or 20 feet, the width narrows down to four or five feet, and the manganese content increases. A sample of picked manganese ore gave 43.7 per cent manganese. Doubtless, much of the ore smelted in the furnace was gathered from off the top of the ground.

In 1909 a party of Knoxville capitalists did some prospecting upon this property, and in addition to sinking a small shaft on the site of the old cut, opened it in several other places some 600 feet southwest along the vein. Two openings had been made on either side of a deep hollow about 150 feet apart. One was badly caved and only the material on the dump could be examined. This proved to be a lean sulphide of iron, with some manganese. The other opening was a short tunnel 25 feet long. The breast of the tunnel shows very little ore of any kind. Evidently, the iron and manganese ores near the surface are the result of a secondary enrichment. Below this zone, which is a shallow one, the sulphide, the primary source of the iron, occurs sparingly with manganese oxide. The property is known as the Annie Owen's tract.

The continuation of the Chilhowee Mountain area from Blount County into Sevier County has already been mentioned. There are several pockets of limonite scattered through residual clays from the Knox dolomite.

### WASHINGTON AND UNICOI COUNTIES.

These two counties will be considered as a unit, since the chief producing area lies within the two counties and is a geological unit.

*Bumpass Cove.*—The entire production from these two counties has come from Bumpass Cove, about two miles southwest of Embreeville. This is one of the oldest and best known iron mining districts in East Tennessee. The town of Embreeville is situated about 11 miles southwest of Johnson City, and is reached by the Embreeville branch of the Southern Railway. In the early 90's a modern blast furnace was put in here near the site of an older blast furnace and rolling mill which was built nearly 80 years ago. The property, now held by the Embree Iron Company, has passed through a number of hands. The present furnace was constructed by an English company—The Embreeville Freehold, Land, Iron and Railway Company, Ltd., in 1892. It ran about a year, making a low grade iron, and was closed in 1893, and remained closed until 1895. The property then passed into the hands of a Mr. Parker, of London, England, who repaired it, and it was again started, with bet-

ter success. Finally it passed out of the hands of the Englishmen to the control of the present owners. The furnace has not been active since early in 1910, and the company has for some time been in the hands of a receiver. The pig iron has always been unusually low in phosphorous for ores of this class, very low in sulphur, and with 0.4 to 0.6% manganese. The tensile strength is very high, tests showing it to be 24,000 pounds per square inch. The iron deposits in Bumpass Cove are embraced under classes 2 and 4.

The area and depth of the different banks varies considerably. The largest would not exceed four or five acres. The depth of material removed ranged from only a few feet to as much as 50 feet. Owing to the method of mining, which with but two exceptions, is by hydraulicing, and the irregular nature of the pockets, it has not been the practice to remove the barren overburden, which varies much in thickness. With the leaner ores, and those mixed with considerable surface dirt, the proportion of ore to dirt, by volume, may be as low as 1 to 12 or lower, while with the richer portions one-half the volume may be ore.

Associated with the ores is a small, but usually persistent quantity of zinc, and in places considerable lead. In smelting the ores a certain amount of zinc dust, consisting principally of the oxide of zinc, is always recovered in the down-comers and flues, and shipped to the zinc smelters.

The large amount of water under high pressures, which is necessary to hydraulic the dirt, is supplied from a large central pumping plant situated on the Nolichucky River. This pump furnished the supply to secondary pumping plants situated at the several washeries, which pump the water through separate pipe lines to the different banks. Figures are not available showing the cost of this kind of mining, but doubtless in the case in question, with so many separate pumping plants, it has been a large item.

There are five washeries in the cove to clean the wash ore from each of the principal banks. With the exception of the bedded ores—class 2—and the ore from the Red Cut bank, all the ore is first sent to log washers. The scheme of treatment is practically the same in all, and the flow sheet for any one washery is as follows:

1. The wash dirt is carried from the bank in cast iron sluices from distances of 1,000 feet or more, and delivered to

2. Grizzly over the lower end of the log trough, with bars set three inches apart. The coarse waste is picked out, and the undersize is sent to the log washer, which yield two products, viz., overflow to waste, and heads sent to

3. Dewatering trommel, with about a 20-mesh screen supported on a cast iron grating, forming the side of trommel. The undersize goes to waste, and the oversize to the picking and conveying belt, where the waste

is picked out and delivered to bins. The picked ore is carried on the belt and discharged into ore bins. Washed ores carry from 40 to 45% iron. Owing to the large amount of very fine particles of ore in the dirt, the richness is not always apparent.

The logs used in all the washeries are oak.

The Embree Iron Company, in addition to its large holdings in Bumpass Cove, also owns large areas of mineral land along Cassi Creek, in the vicinity of Green Ridge, near the intersection of Greene, Washington and Unicoi counties. Some prospecting has been done recently, and with fair results; but this tract was not examined. At present it is rather remote from transportation.

The bedded deposits—class 2—occur in Cochran conglomerate, which outcrops on the south side of the cove. The ore occurs as an interstratified deposit, with sandy shales above and massive dark red sandstones beneath. The bed, which has been opened in a number of places, shows a well defined upper and lower vein, of about the equal thickness. These vary from 10 to 18 inches, and are separated by a sandstone parting from 16 to 24 inches thick. The ore breaks into blocks and is generally low grade, as the following analyses show:

*Table of analyses of iron from Bumpass Cove.*

| Sample | Iron per cent | Silica per cent | Lime (CaO) |
|---|---|---|---|
| Select ore ............................... | 40.1 | 36.8 | 1.0 |
| General average ........................ | 30.8 | 48.6 | 1.4 |
| A sample from the underlying red sandstone beds gave: | | | |
| | 15.8 | 73.6 | 0.8 |

In the early days of the English occupancy it is said these bedded ores were utilized in the furnace, but in recent years nothing has been done with them.

The second and by far the most important deposits are the pocket deposits in the residual clays overlying the Shady limestone. These deposits occur on both the northwest and southeast side of the cove. The principal banks on the northwest side of the cove are as follows:

*Polly Hollow and other banks.*—Polly Hollow is one of the largest banks, and is situated about 250 feet above the floor of the cove. Parts of this bank are covered with a heavy burden of wash and loose rock. The ore occurs distributed irregularly through yellow clay, sandy in parts, and has associated with it small veinlets of manganese oxide. The deposits rest upon the rough, pinnacled limestone.

The West bank, situated about a mile southwest of Polly Hollow, is similar in all respects to it. The territory lying between these two banks has been prospected more or less, and the continuity of the two is fairly certain. It is hardly likely, however, that all the ground between the two banks will ever pay to work.

Towards Embreeville, and near the bottom of the cove, is another old bank which has been exhausted.

Fowler bank, on the southwest side of the cove, has been extensively worked. The ores are distributed through a deep red clay, and above the pinnacled limestone. It is said that small amounts of lead sulphite were found in places scattered through this limestone.

*Red Cut bank.*—This bank has been operated as a solid ore bank, i. e., one in which it is not necessary to wash the ore. The ore, a limonite, which changes in places to a true hematite, occurs as a more or less regular bed overlying the limestone, and following roughly the contour of the surface. Here is a case where doubtless the mineral bearing solutions have been richer in iron than the average.

Another bank lies directly northwest of the preceding, and yields both wash and solid ore. It is therefore quite certain that it is but a continuation of the Red Cut bank.

*Klondyke bank.*—This is similar in all respects to the Fowler bank.

There are other banks or pockets that have been operated more or less extensively. The banks on the southeast side of the cove are not so high above the valley as those on the northwest side.

## BIBLIOGRAPHY OF EAST TENNESSEE IRON ORES.

The following titles and references are given from among a number of articles that have appeared from time to time.

1. *The Geology of Tennessee,* James M. Safford, 1869.—Discusses in a masterly way the principal features of the State. For many years this report has been, and is still, one of the best authorities on the subject.

2. *The Resources of Tennessee,* by J. B. Killebrew, 1875.—This work touches in a general way on the geology of the State, but it is concerned chiefly with a description of the various natural resources.

3. Atlases, published by the U. S. Geological Survey. The entire area under consideration is covered by topographic sheets, and with the exception of three quadrangles, the entire area is now covered by the geologic folios. The separate counties herein mentioned are covered by the following geologic folios, or topographic sheets:

*Table of Folios and Topographic Sheets.*

| County | Folio No. | Name of | Folio |
|---|---|---|---|
| Blount | 16 | Knoxville | |
| " | 25 | Loudon | |
| " | 143 | Nantahala | |
| " | | Murphy | Topographic Sheet |
| Carter | 152 | Roane Mountain | |
| " | 90 | Cranberry | |
| Cocke | 118 | Greeneville | |
| " | 27 | Morristown | |
| " | 116 | Asheville | |
| " | | Mt. Guyot | Topographic Sheet |
| Greene | 118 | Greeneville | |
| " | 27 | Morristown | |
| Johnson | 90 | Cranberry | |
| " | 152 | Roane Mountain | |
| " | | Abingdon | Topographic Sheet |
| Polk | | Elijay | Topographic Sheet |
| " | | Murphy | Topographic Sheet |
| " | | Ducktown Special | |
| Sevier | 16 | Knoxville | |
| " | 75 | Maynardville | |
| " | | Mt. Guyot | Topographic Sheet |
| Washington | 116 | Asheville | |
| and Unicoi | 118 | Greeneville | |
| " | 152 | Roane Mountain | |
| " | 124 | Mt. Mitchell | |
| Monroe | 25 | Loudon | |
| " | | Murphy | Topographic Sheet |

As is generally known, these folios may be had for the sum of 25 cents each, by sending to the Director of the U. S. Geological Survey, Washington, D. C. Each folio gives a topographic map of the quadrangle, usually to a scale of about one-half mile to the inch, with a contour interval of 100 feet. Also geologic maps giving the areal and economic geology and cross sections, together with a concise discussion of the geographic, geologic and economic features of the area covered.

4. *Trans. Amer. Ins. of Min. Engrs.*, Vol XV, p. 170. The Iron-Ores and Coals of Alabama, Georgia and Tennessee (1886). Discusses the geology of the region, gives classification of ores, coals, etc., together with many analyses.

*Trans. Amer. Inst. Min. Engrs.*, Vol. XXV, p. 551 (1895). Southern Magnetites and Magnetic Separation. Discusses the Cranberry Magnetite belt, and gives a number of analyses of the magnetite ores from both North Carolina, and Carter County, Tenn.

*Trans. Amer. Inst. Min. Engrs.*, Vol. XXVI, p. 138 (1896). The Embreeville Estate, Tennessee. Paper discusses the nature of the ore deposits in Bumpuss Cove, their reduction, character, etc.

*Trans. Amer. Inst. Min. Engrs.*, Vol. XXIX, p. (1908). A New Theory of the Genesis of Brown Hematite Ores, and a New Source of Sulphur Supply. Discusses in general the brown ores that are found scattered along the Appalachians from New York to Alabama.

5. *Eng. and Min. Jour.*, Vol. LXXVIII, p. 590. Description of the Shady Valley deposits, Vol. LXXVIII, p. 742. Cursory description of East Tennessee ore deposits.

ACKNOWLEDGMENTS.

The writer wishes to acknowledge the many courtesies that have been extended to him. Among those who have given time and advice may be mentioned: Mr. John N. Adams, Del Rio, Tenn.; Mr. J. C. Campbell, and Mr. H. H. Hurley, of Johnson City; Mr. J. S. Park, Esq., Greeneville, Tenn., and Mr. R. L. Seaver, Afton, Tenn.; Mr. C. A. Morris, Store Manager, Embree Iron Company, Embreeville, Tenn.; and Mr. D. C. Williamson, Walland, Tenn.

## Publications of Geological Survey of Tennessee Issued.

The following publications have been issued by the present Survey, and will be sent on request *when accompanied by the necessary postage.* To make it possible for libraries to complete their sets, and for persons having real need for any of the volumes to obtain the earlier ones at small cost, 500 copies of each report are reserved for sale, at the cost of printing; the receipts from the sales being turned into the State Treasury.

Gaps in the series of numbers are of reports still in preparation:

**Bulletin No.** 1—Geological Work in Tennessee.

A. The establishment, purpose, object and methods of the State Geological Survey; by George H. Ashley, 33 pages, issued July, 1910, postage, 2 cents.

B. Bibliography of Tennessee Geology and Related Subjects; by Elizabeth Cockrill, 119 pages; postage, 3 cents.

**Bulletin No.** 2—Preliminary Papers on the Mineral Resources of Tennessee, by George H. Ashley and others.

A. Outline Introduction to the Mineral Resources of Tennessee, by George H. Ashley, issued September 10, 1910; 65 pages; postage, 2 cents.

D. The Marbles of East Tennessee, by C. H. Gordon; issued May, 1911; 33 pages; postage, 2 cents.

E. Oil Development in Tennessee, by M. J. Munn; issued January, 1911; 46 pages; postage, 2 cents.

G. The Zinc Deposits of Tennessee, by S. W. Osgood; issued October, 1910; 16 pages; postage, 1 cent.

**Bulletin No.** 3—Drainage Reclamation in Tennessee; 74 pages; issued July, 1910; postage, 3 cents.

A. Drainage Problems in Tennessee, by George H. Ashley; pages 1-15; postage, 1 cent.

B. Drainage of Rivers in Gibson County, Tennessee, by A. E. Morgan and S. H. McCrory; pages 17-43; postage, 1 cent.

C. The Drainage Law of Tennessee; pages 45-74; postage, 1 cent.

**Bulletin No.** 4—Administrative Report of the State Geologist, 1910; issued March, 1911; postage, 2 cents.

**Bulletin No.** 5—Clays of West Tennessee, by Wilbur A. Nelson; issued April, 1911; postage, 4 cents.

**Bulletin No.** 9—Economic Geology of the Dayton-Pikeville Region, by W. C. Phalen, for sale only, price 15 cents.

**Bulletin No. 10**—Studies of the Forests of Tennessee.

A. An Investigation of the Forest Conditions in Tennessee, by R. Clifford Hall; issued April, 1911; 56 pages; postage 3 cents.

B. Chestnut in Tennessee, by W. W. Ashe, issued December, 1911; postage, 2 cents.

**Bulletin No. 13**—A Brief Summary of the Resources of Tennessee, by Geo. H. Ashley; issued May, 1911; 40 pages; postage, 2 cents.

**"The Resources of Tennessee**—A monthly magazine, devoted to the description, conservation and development of the State's resources. Postage, 2 cents a number.

PRINCIPAL PAPERS.

Vol. I. No. 1—The utilization of the small water powers in Tennessee, by J. A. Switzer and Geo. H. Ashley.

No. 2—The Camden chert—an ideal road material, by George H. Ashley.
The Fernvale iron ore deposit of Davidson County, by Wilbur A. Nelson.
Cement materials in Tennessee, by C. H. Gordon.

No. 3—The gold field of Coker Creek, by Geo. H. Ashley.

No. 4—Coal resources of Dayton-Pikeville area, by W. C. Phalen.

No. 5—Economic aspects of the smoke nuisance, by J. A. Switzer.
Watauga Power Company's hydro-electric development, by Francis R. Weller.
The coal fields of Tennessee, by Geo. H. Ashley.

No. 6—Bauxite Mining in Tennessee, by Geo. H. Ashley.
A New Manganese Deposit in Tennessee, by Wilbur A. Nelson.
Road Improvement in Tennessee, by Geo. H. Ashley.

Vol. II. No. 1—The Utilization of the Navigable Rivers of Tennessee, by Geo. H. Ashley.
Dust Explosions in Mines, by Geo. H. Ashley.
The Rejuvenation of Wornout Soil Without Artificial Fertilizers, by Geo. H. Ashley.
Tennessee to Have Another Great Water Power, by George Byrne.
Manufacture of Sulphuric Acid in Tennessee in 1911, by W. A. Nelson.

No. 2—The Ocoee River Power Development, by J. A. Switzer.
Exporation for Natural Gas and Oil at Memphis, Tenn., by M. J. Munn.

No. 3—The Power Development at Hale's Bar, by J. A. Switzer.
Notes on Lead in Tennessee, by Wilbur A. Nelson.

No. 4—The Tennessee Academy of Science.
The Preliminary Consideration of Water Power Projects, by J. A. Switzer.
Lignite and Lignitic Clay in West Tennessee, by Wilbur A. Nelson.

No. 5—The Growth of Our Knowledge of Tennessee Geology, L. C. Glenn.

No. 6—On the Impounding of Waters to Prevent Floods, by A. H. Purdue.
Drainage Problems of Wolf, Hatchie, and South Fork of Forked Deer Rivers, in West Tennessee, by L. L. Hidinger and Arthur E .Morgan.
The Waste From Hillside Wash, by A. H. Purdue.

No. 7—Where May Oil and Gas Be Found in Tennessee? By Geo. H. Ashley.
Spring Creek Oil Field. By M. J. Munn.

No. 8—The Monteagle Wonder Cave. By Wilbur A. Nelson.
Cave Marble (Cave Onyx) in Tennessee. By C. H. Gordon.

# NEW PUBLICATIONS

## TO PUBLISHERS OF NEWSPAPERS, MAGAZINES AND TECHNICAL JOURNALS:

**There are over 2,000,000 people in Tennessee, and some outside. As only 3,000 copies of the Survey's publications are printed, it is realized that if the people of the state, and outside of the state, are to be benefited in any large measure from the work of the Survey, it must be through the co-operation of the newspapers, magazines, and technical journals. Therefore the statements of the results of the Survey's work and reviews of its new publications are cast in form suitable for use by publishers in the hope that they will co-operate in extending the benefits of the Survey's studies by making liberal use of any or all of the matter in this journal.**

## THE ZINC DEPOSITS OF NORTHEASTERN TENNESSEE.

By A. H. Purdue.

The State Geological Survey has just published a detailed report on the zinc deposits of northeastern Tennessee. This report, which covers about 70 pages, is profusely illustrated by diagrams, showing the origin and occurrence of the ores, and by half-tones, showing the deposits and the mining that is already being done.

The ores occur in several groups along Holston and Powell rivers, Straight Creek, and Fall Branch, and around Jearoldstown. A most interesting chapter is on prospecting and how it should be carried on. In connection with this a few words are said about faults, or breaks in the rocks, for it is along these breaks that most of the zinc ores are found. The following extract is taken from the last pages of the bulletin:

"From the best that one can judge under the present conditions of development, the possibilities of the zinc industry in northeastern Tennessee are large, provided those engaging in the industry use the greatest possible economy and employ the best engineering talent. The company that fails to observe either of these requirements is doomed to failure. Mining for carbonate ore may be done on a small scale, but as a rule, mining for blende must be on a large one."

## LET TENNESSEE DEVELOP HER IRON ORES.

The people of East Tennessee long ago recognized that the development of their region depended largely on transportation facilities, and as they thought they possessed rich mineral resources, they proceeded to get the railroads.

There are places in East Tennessee that are as well situated for the erection of furnaces as the well known Birmingham region. Iron occurs in abundance on the sides of the hills and the mountains, while not a stone's throw away are found unlimited supplies of fluxing material. Again, their next door neighbor is the Cumberland Mountains, filled to overflowing with coal beds, which are at present mined and coked for use in the few furnaces of this region.

Tennessee has twenty-four iron furnaces in its borders, and most of these are located in the eastern section, where the conditions are ideal.

The brown ores of East Tennessee are found in a belt which comprises the eastern border counties of Tennessee, from Johnson in the extreme north to Polk in the southeast.

Feeling the need of a preliminary report on these ores, the State Geological Survey has just published an article on "*The Valley and Mountain Ores of East Tennessee*," by Dr. Royal P. Jarvis, which appeared in the September number of the *Resources of Tennessee*, and can be procured by writing to the Geological Survey at Nashville.

The six different classes of ore found in this region are taken up and described, as well as the formations in which they occur. A table of the different formations is given, showing in chronological order their thicknesses and characteristics.

Of the ores, the limonite, or brown hematite, as it is called, is the most abundant, and it occurs as pockets and blanket deposits over large areas. Much mining has been done in the past on these ores. They are probably some of the first ores used in the United States for the manufacture of iron, for in the days before the Civil War this region was dotted with small charcoal iron furnaces or "bloomeries" as they were then called. The fallen-in ruins of some of these first furnaces, which were built of limestone blocks, still remain, and are peculiar sights when compared to our most up-to-date blast furnaces. Tennessee was noted for its charcoal iron, and the high place that it held is testified to in that it was generally the iron specified in the government contracts of that day.

The bedded hematite also occurs, but not as abundantly as in the region just west of this one.

One of the most remarkable deposits found is that of the magnetic iron, or magnetite which occurs in Carter and Unicoi counties, and extends over the border into North Carolina. It is being utilized in the furnaces of Johnson City.

Another type of ore is the gossan deposit, which occurs at Ducktown, which in the past has been a source of much ore, and still is mined to some extent.

The report on the ores deal with them by counties, and should be of much help to those interested in the minerals of this region. The different deposits are taken up and their extent and value discussed. The iron situation in East Tennessee reminds one of the fable of the race between the tortoise and the hare. Like the hare Tennessee many years ago got a good start, but on outdistancing her rivals she went to sleep and let the others overtake and far succeed her. Let Tennessee wake up and start as of old and show the other states what unlimited resources she has that have been lying idle.

# News Notes

Dr. A. H. Purdue has just returned from a trip to Wayne County, where he examined the geology and iron ores of that region. A topographic map, by the U. S. Geological Survey, was made of this region in 1902-3, but the geology has never been worked out. Recent observattons by Dr. Purdue shows that the map is very accurate and that it would be very feasible to do up-to-date geologic mapping on this old base map.

Mr. Wilbur A. Nelson, Assistant Geologist, spent the first part of the month of August on the Agricultural Special train, representing the Geological Survey. While with the train he made several short talks on the work of the Survey and of the great help this department is to the farmer, especially in the soil maps that the Survey is having made of the different counties of the State in coöperation with the United States Bureau of Soils. Minerals were examined at every stop, and information given the crowds in regard to the minerals which occurred in the respective localities where stops were made.

It would be hard to estimate the great amount of good that this train has done to the farmers of the State in the two months' trip that has just been brought to a successful finish. Every town of importance in the State was visited, and the enthusiasm that was manifested by the farmers show how great is their appreciation. The enthusiasm of the members of the train was as great the last week of the trip as on the first day and great credit should be given them and Captain Peck, Commissioner of Agriculture, who, in spite of the predictions of many that the entire schedule would never be completed, carried it out in full and with great success.

Mr. W. E. Wrather, geologist from Houston, Texas, who is employed by some capitalists, spent part of the last month in East Tennessee looking into the practicability of establishing a large marble mill and quarry in that section of the State.

Mr. Wilbur A. Nelson has in the past month made trips to Monterey, Sewanee and Hollow Rock in course of preparing an article on "Some of the Building Sands of Tennessee," which will appear shortly in this magazine.

Dayton Coal and Iron Company's furnace, Dayton, Tenn.

Chattanooga Iron Company's furnace, Chattanooga, Tenn.

TWO OF THE IRON FURNACES IN EAST TENNESSEE.

BULLETIN 2-D

PLATE I. Quarry of the Evans Marble Company, near Friendsville, Tennessee.
Shows channelers at work.

2-D

STATE OF TENNESSEE—STATE GEOLOGICAL SURVEY

GEO. H. ASHLEY, STATE GEOLOGIST

# THE MARBLES OF TENNESSEE

BY CHAS. H. GORDON

EXTRACT (D) FROM BULLETIN No. 2, "PRELIMINARY PAPERS ON THE MINERAL RESOURCES OF TENNESSEE."

NASHVILLE

1911

# CONTENTS

## LIST OF PLATES

# The Marbles of Tennessee

BY C. H. GORDON.

## INTRODUCTION.

In the trade the term marble is applied to any calcareous rock capable of taking a good polish, and which is suitable for ornamental work, or high-grade construction. For commercial use the rock must be of desirable color, must quarry in blocks of large size free from cracks or impure layers, and be of fine close texture. These conditions are met with most largely in crystalline limestones or dolomites, though locally other deposits, such as breccias, conglomerates, and even serpentines, may furnish material suitable for ornamental construction, but strictly speaking, not all of these can be considered marbles. A true marble is a granular aggregate of crystals of calcite or dolomite, chiefly the former. Usually the crystals are of uniform size in the same marble, but may vary widely in marbles from different localities or from different beds. Certain marbles characterized as *variegated* owe their special properties to variation in color and size of crystals in different areas. The fine white varieties, which appear like loaf sugar, are called *saccharoidal.*

Most limestones were formed by the deposition of sediment on the bed of the sea, and the characters which render them suitable for use as marbles, are the result of physical and chemical changes undergone subsequent to their deposition. The variations in character of marbles are due both to differences in the sediment at the time of its deposition, and also to the differences in the changes which the rock has subsequently sustained.

## DISTRIBUTION OF MARBLES IN TENNESSEE.

*East Tennessee*—The marbles of Eastern Tennessee occur at different horizons of the paleozoic series of rocks, but the chief deposits of this section and of the State, constitute what is known as the Holston member of the Chickamauga, a widely extended limestone formation, the major part of which is unsuited for use as marble. The Holston beds are confined to the Tennessee Valley and outcrop in several more or less parallel belts as shown on the accompanying map. The marble area as a whole averages about twenty miles in width, and extends from near the Virginia line southwestward to McMinn County, a distance of over one hundred and twenty-five miles. Originally the deposit was co-extensive with the area thus outlined, but much of it has been removed by erosion. The area is traversed throughout its longitudinal extent by the Southern Railway, and transversely by the Louisville and Nashville Railroad. Commercial material is not available throughout its outcropping area, but conditions favorable for commercial development exist in many places, and the amount of marble available is practically inexhaustible.

Beds of marble similar to the Holston marble occur in the Sevier shales of Knox and Sevier counties, and have been worked to some extent. A black marble is found in a number of counties in eastern Tennessee. It is quite compact, sometimes beautifully streaked with white calcite, and takes a fine polish. This marble was used to form the bases of the columns in the senate chamber of the State Capitol at Nashville. A green serpentinous marble has been reported from Union County, but the relations of the deposit and its extent are not known, only small specimens of the stone having been seen by the writer. A magnesian marble of impure quality occurs in the Knox dolomite in places, and in Blount, Monroe and McMinn counties are conglomerates and breccias which, when polished, resemble mosaic work. Beds of breccia on the Little Tennessee, south of Chilhowee Mountain, sometimes supply a beautiful stone, the angular fragments of different colors, when polished, presenting a pleasing effect. Similar beds occur in Greene, Cocke and Sevier counties, but they are not much worked owing to the hardness of some of the angular fragments. The rock is not strictly a marble, as it is not wholly crystalline, and, moreover, it is limited in quantity.

*Middle and West Tennessee*—Red variegated marbles are found in a number of the counties west of the Cumberland Table-land, notably on Elk River in Franklin County, and at the Oil Springs on Leiper's Creek in Maury County. Variegated marbles occur also in western

Tennessee in the counties of Henry, Benton, Perry, Decatur, Wayne and Hardin. Though somewhat inferior to those of the East Tennessee Valley they, nevertheless, are valuable stones. A fawn-colored or brownish red marble is found on Shoal Creek in Lawrence County. A specimen of a similar stone from the same or a neighboring locality, now in the collections of the University of Tennessee, has been mistaken for a noted French marble. The Shoal Creek beds are about 40 feet in thickness, and outcrop on both sides of the creek for a distance of 15 miles. Merrill states (a) that the stone is often variegated

*a.* George P. Merrill, Stones for Building and Decoration, p. 230.

by fleecy clouds of green, or red, green and white colors. Dove-colored marbles, some of fine quality, are met with in Wilson, Davidson and Coffee counties, and in Rutherford County is a pale yellow marble with serpentine veins of red and black dots. An olive-green marble is said to occur in Davidson County, though the extent of the deposit is not known.

*Onyx Marbles*—Under the term *onyx* or *onyx marble* two quite distinct types of rock are included, both in their chemical composition consisting essentially of carbonate of lime and mineralogically of calcite. (b) Both differ from marbles of the common type, however, being

*b.* Ibid, p. 242.

purely chemical deposits rather than products of metamorphism of pre-existing calcareous sediments. The distinction between the two types of onyx marbles is that one is a product of deep-seated hot-spring water—that is a travertine—while the other is a deposit by cold water upon the floor, roof and walls of limestone caverns, or in rifts and cracks in the limestone itself. In other words, it is a stalagmitic or stalactitic deposit. Strictly speaking, the term onyx belongs to a purely siliceous rock, a banded variety of chalcedony. Its application to the calcareous rock is due to the resemblance of the latter in banding and translucency to the true onyx.

Of the two kinds of onyx marbles, only the cave marbles are found in Tennessee. Water percolating downward through the soil becomes charged with carbonic acid, which increases its capacity to dissolve limestone. Filtering downward through the cracks and fissures of the limestone it enlarges the openings, forming caves and caverns. After a time, however, a new process sets in whereby there is deposited upon the floor, walls and roof the material gathered by the water in its passage through the rock. This is mostly pure calcium carbonate, with small amounts of iron oxide or other coloring matter, to produce the banding usually seen. A characteristic of cave marbles is the presence of mechanical impurities in the form of ochreous residual clays, and

the absence of appreciable quantities of metallic oxides a feature in which they are distinguished from deposits of spring origin.

Cave marbles vary greatly both in extent and quality. They may occur only as a mere veneering over the surface of the rock or as a local accumulation of small extent. The appearances of such surface deposits are often deceptive, suggesting an abundance, whereas the amount of available stone is extremely small. Deposits of these marbles are rarely uniform over any great distance, and, moreover, owing to their coarse crystallization, they are likely to contain numerous cavities and pores known as "thumb-holes" and "pin-holes," which materially injure the quality of the stone. The colors are usually light and dull, and the rock as a rule is less translucent than true onyx marbles. White, yellowish amber and reddish colors, with resinous lustre, are common, and sometimes very beautiful material is found.

There are numerous caves in the limestone regions of eastern Tennessee, the walls of which are encrusted with deposits of cave onyx. Many of these are laid open by denudation, and their former existence recognized only by the veneering of cave marble on the exposed rock surface. In the main these accumulations are small and of no commercial value, but not infrequently they may yield blocks of beautiful material. Instances are cited where appearances indicate a solid mass of merchantable stone 100 feet long by 20 or 30 feet in height, but which on inspection is found to be only a thin coating of stalactitic matter over the sloping wall of an old cavern with not a cubic yard of merchantable stone in the entire outcrop. (a)

Some deposits of cave marbles properly managed may be worked up to good advantage, but too much must not be expected of them. Merrill states that disregard of this fact has led to disastrous failures following every attempt thus far made to work the cave marbles of America. He says: "If the material as taken from the ledge could be assorted by some competent person and worked up, each block for a purpose of ornamentation to which it seemed best adapted, then we might hope for some interesting results. But at best the cave marbles of America must rank as "uniques" rather than objects of commercial value. They will never become sources of regular supply. There is too much waste and too much uncertainty regarding amount and quality."

Some broken down caves in Anderson, Union, Hawkins and other counties in Eastern Tennessee have yielded interesting specimens of cave marble, and the attempt is now being made to quarry a deposit in the first named county from which some very beautiful material has

*a.* George P. Merrill, Stone for Building and Decorating, p. 248.

been obtained. The material is best adapted for small ornaments, vases, columns and certain forms of base relief, and it is of little use to seek a market for it in other lines of work.

## Geology of the Holston Deposits.

The rocks appearing at the surface of the Tennessee Valley are for the most part of sedimentary origin—that is, they were deposited by water.

They consist of sandstones, shales and limestones, all presenting great variety in composition and appearance. The materials of which they are composed were originally gravel, sand and mud, derived from the waste of older rocks and the remains of animals and plants which lived while these strata were being laid down. These rocks afford a record from early Cambrian very nearly through Carboniferous time. Hence they represent practically the whole of the Paleozoic.

### Table of Paleozoic Formations in East Tennessee.

Table of Paleozoic Formations in East Tennessee.

| | Symbol |
|---|---|
| *Pennsylvanian* | |
| Anderson Sandstone | Pa |
| Scott Shale | Ps |
| Wartburg Sandstone | Pw |
| Briceville Shale | Pb |
| Lee Formation | Pl |
| *Mississippian* | |
| Pennington Shale | Mp |
| Newman Limestone | Mn |
| *Devonian* | |
| Grainger Shale | Dg |
| Chattanooga Shale | Dc |
| *Silurian* | |
| Rockwood Formation | Sr |
| Clinch Sandstone | Sc |
| Bays Sandstone | Sb |
| *Ordovician* | |
| Sevier Shales | Os |
| Tellico Formation | Ot |
| Tellico Sandstone—Moccasin Limestone | Ott-Otm |
| Athens Shale | Ota |
| Chickamauga Formation | Oc |
| Lenoir Limestone—Holston Marble | Ocl-Och |
| Knox Dolomite (in part) | Ok |

*Cambrian*

| | |
|---|---|
| Knox Dolomite (in part) | |
| Conasauga Formation | Cc |
| Nolachucky Shale | Ccn |
| Honaker Formation | Cch |
| Maryville Limestone | Cchm |
| Rogersville Shale | Cchr |
| Rutledge Limestone | Cchrt |
| Watauga Formation | Cw |
| Watauga Shale—Rome Sandstone | Cww-Cwr |
| Shady Limestone | Cs |
| Erwin Quartzite | Ce |
| Hampton Formation | Ch |
| Murray Slate | Chm |
| Nebo Quartzite | Chn |
| Nichols Slate | Chni |
| Unicoi Formation | Cu |
| Cochran Conglomerate | Cuc |
| Hiwassee Slate | Cuh |
| Snowbird Formation | Cus |

*Pre-Cambrian*

| | |
|---|---|
| Beech Granite—Cranberry Granite | PCb |
| Talc and serpentine rocks | PCt |
| Roan Gneiss—Carolina Gneiss | PCr-PCCc |

The rocks underlying most of the Great Valley belong to the Paleozoic series and chiefly to the three lower divisions, viz.: Cambrian, Ordovician and Silurian. The marbles occur in the Chickamauga limestone formation, which is near the middle of the Ordovician. The Chickamauga lies over the Knox dolomite, and is itself overlain by the Athens shale, the Tellico sandstone and the Sevier shale, named in ascending order, representing the Trenton and Nashville series of Safford. It has received its name from Chickamauga Creek in Hamilton County, Tennessee. The marble beds which constitute portions only of the Chickamauga formation are for the most part coarsely crystalline, but they include also layers of shaly marble and shale.

The marble beds occur in lentils in the Chickamauga formation, in some cases at or near the base, in others within or near the top of the formation. Underlying the marble is the Lenoir limestone which constitutes the basal member of the Chickamauga formation. This member consists at the base of massively bedded, compact, bluish gray limestone usually speckled with small white patches of calcite. Overlying these beds are others of gray argillaceous limestone, whose weathered surfaces present a characteristically lumpy or knotty appearance by which the beds are easily recognized.

These beds are highly fossiliferous, especially the argillaceous portions, as well as the marbles themselves, though the fossils are usually not easily separated from the rock. In the marble the form of the fossils is readily seen though they have been wholly recrystallized.

Toward the southeast the marble beds lie at or near the top of the Chickamauga formation, the Lenoir beds in this region having a thickness of 500 to 700 feet. Northwest of Clinch Mountain, however, the marbles occur near the base, the Lenoir beds being reduced to a few feet in thickness, and in places are absent altogether apparently. Between the marble belt and the Cumberland Plateau, limestones of the Lenoir type represent the whole of the Chickamauga, and with some of the overlying formations present a thickness of nearly 2,000 feet. The exact relations of these to the formations of the east side of the Great Valley has not been determined, but it is evident the differences thus shown are due to the deepening of the waters in which the sediments were deposited toward the northwest. It is inferred the shore from which materials were derived lay toward the east or southeast, and hence the formations on that side of the valley would receive more of the shore material. At the time the marbles were laid down the area in which they occur appears to have been an area of clear waters filled with an abundance of marine life such as corals, crinoids, brachiopods, gasteropods and cephalopods, whose recrystallized remains make up the bulk of the rock.

On account of their characteristic appearance and economic importance these closely crystallized stratas have been given the distinctive name of "Holston Marble," from the main fork of the Tennessee River which traverses a considerable part of the region in which they occur. The beds have a thickness of from 250 to 400 feet, thickening from northeast to southwest. Portions only of the full thickening in any locality are available for quarrying, workable beds being rarely over 50 feet thick, though other beds adapted for working may come in at higher or lower levels. Quarries far separated from each other have quite distinct series of beds, and each quarry has its special variety of marble.

*Geologic Structure of the Region*—The rocks of the Tennessee Valley region have been disturbed from the horizontal position in which they were originally deposited and tilted, bent and broken to a high degree. The folds and faults trend with the course of the Valley, which is approximately parallel with the shore line of the ancient continent from which the sediments were derived. In places the effects of metamorphism are seen in the alteration of certain beds to slates. The folds are long and straight and usually closely compressed and

squeezed up so far that they either broke along the northwest side of the anticline or were overturned in that direction. Hence the faults appear along the northwest sides of the anticlines, with the fault planes dipping from 20 to 60 degrees (most of them about 45 degrees) toward the southeast. The dip of the beds varies from flat to vertical or 50 degrees overturned, but for the most part the dip is from 30 to 40 degrees toward the southeast. Where the dip is toward the northwest it reaches 80 to 90 degrees.

The faults are numerous, and in some cases extend for great distances in comparatively straight lines. Of these, two are especially noteworthy, as they extend entirely across the State of Tennessee, following the Great Valley, and into adjoining States. These are the Clinch Mountain fault and the Hunter Valley fault, which have been traced continuously for over 350 miles. The Clinch Mountain fault follows the east side of Clinch Mountain, passes just north of Knoxville, near Smithwood, and crosses the Tennessee River about 2½ miles northwest of Loudon.

In most of the faults the displacement is from one to three miles. There are numerous small faults, having a displacement of a few feet, while in some faults the displacement may be as great as five miles.

Much variation is shown in the manner in which the rocks yielded to the pressure, which caused the folding and faulting. Massive rocks like the Knox dolomite and the sandstones of Chilhowee Mountain bent in great curves or were broken and pushed over by the lateral thrust. In some cases, however, even such massive beds as the Knox dolomite yielded in a close fold without breaking, as shown on the Nolachucky River northeast of Embreeville. Thin-bedded shales and sandstones, like the Athens and Tellico formations, and Sevier shales, were puckered and contorted owing to their readiness to yield to the pressure and to slip along their bedding planes.

Various exposures in the vicinity of Knoxville show this tendency of the Tellico formation to adjust itself to compression by close folding and contortion of the thin beds.

The condition in which the rocks of the region are found and the structures here described indicate that the province has been affected by two classes of forces, one acting horizontally and the other vertically. The folding and faulting was evidently the result chiefly of compression, which was exerted in a direction from northwest to southeast, that is at right angles to the trend of the folds and of the cleavage planes.

This compression is considered to have become effective early in the Paleozoic era, but it reached its culmination soon after the close of

the Carboniferous period. The forces which appear to have been exerted vertically had the effect of a general raising or lowering of the surface. While the compressive forces were limited in effect to a narrow zone, the others were exerted over a broader area and were less intense in their effects.

## The Marble Areas.

*Occurrence in Belts*—As shown in the accompanying map, the marbles outcrop in a series of belts trending with the general direction of the folds and faults of the valley. In length the exposures vary from a fraction of a mile to upwards of seventy-five miles in continuous outcrop. In general, the width of each belt does not exceed one-fourth of a mile, but in places a belt may have a width of a mile or more as a result of the flattening of the beds or an increase in their thickness. The belts are widest in the vicinity of Knoxville, a condition favorable to the development of the marble industry in this locality.

The number of distinct belts of marble that may be recognized in the province is seven, in addition to which there are several limited exposures determined by the combined effect of faulting and erosion. Six of these appear in the vicinity of Knoxville. Named in order from northwest to southeast the belts are as follows: Luttrell Belt, Black Oak Belt, Concord Belt, Knoxville Belt, French Broad Belt, and Bays Mountain Belt. Galbraith Belt in Hawkins County may perhaps be considered as a continuation of the Black Oak Belt. Other exposures of limited extent occur for the most part along lines of faulting. These are usually more or less closely related to the main belts, and may therefore be included with them. Such are the areas noted at the Meadow Quarries in Blount County, a small area two and a half miles northwest of Knoxville, the Craighead outcrop four miles southeast of Sweetwater, and the one on the north side of Beaver Ridge, two and a half miles north of Fountain City. Of greater areal extent is that which crosses the Tennessee River at the mouth of Stockton Creek on the boundary line between Roane and Loudon Counties. This deposit is about six miles long by one half mile in width, outcropping around the borders of a lenticular area of Chickamauga limestone. The marble occupies the axis of a shallow syncline, which accounts for its preservation from erosion. The annular outcrop in the vicinity of Straw Plains has a like explanation. This area is not known to have commercial value. As it lies in the line of extension of the Luttrell Belt, it may be considered as an inlier belonging to that belt, the intervening portions having been removed by erosion.

Branching of the belts is not uncommon as a result of the planing off by erosion of the folded and faulted beds. This feature is especially noticeable in the Black Oak and Bays Mountain Belts. Horseshoe-shaped areas, like that seen in the French Broad Belt, are due to the erosion of the crest of dome-shaped folds.

*The Luttrell Belt.*—The Luttrell is the first belt of marble met with in crossing the Great Valley from northwest to southeast. It lies near the outer margin of the marble deposits, no deposits being found north and west of this belt, except a few unimportant beds of gray marble which appear in the next basin north of the Clinch syncline, northeast of Maynardville. Moreover, this belt is the most persistent of the series. Beginning at a point on Beaver Creek, four miles northwest of Fountain City, it extends in a nearly straight line along the south flank of Copper Ridge, northeastward into Hawkins County, a distance of over seventy-five miles. As a consequence of its position near the outer boundary of the area in which the materials of the marble were deposited, the formation is subject to considerable variation and includes a larger proportion of earthy, or shaley matter, than is found near the middle of the marble basin. In this belt the principal quarry beds lie near the base of the Chickamauga, being separated from the Knox dolomite by about thirty to forty feet of the Lenoir beds, the upper half of which consists of gray granular limestones approaching a marble in textural appearance. Moreover, the marble beds are overlain by a series of impure marbles and limestones with more or less shale, and near the top of the formation beds of bluish gray limestone resembling the basal Lenoir beds. Southwest of Luttrell and northeast in Hawkins County, the massive marble beds diminish in thickness and beds of shale increase. Good marble abounds in this belt, however, especially that portion lying in Union and Grainger counties. Owing to the generally narrow outcrops and conditions requiring considerable stripping much of the marble of this belt will not become available until more favorable localities are exhausted. Northeast of Thornhill, in Grainger County, the red marbles disappear and blue and gray marbles only are found. These are of good body, however, but lack the most prized color.

The only important quarries located on this belt are those at Luttrell and five miles northeast at Powder Spring. The latter are not now being operated.

*The Black Oak Belt.*—Next in the series is the Black Oak Belt, which makes its appearance at Corryton and extends southwest along the south side of Black Oak Ridge, passing through Fountain City. Five miles northwest of Knoxville the belt is cut off by a fault, but

reappears six miles farther on, and continues thence into Monroe County. The Clinch Mountain fault lies close to the belt on the southeast. Between Corryton and Maloneyville the outcrop is from a half to three-quarters of a mile in width, but throughout the remainder of its course it rarely exceeds one-fourth of a mile. Associated with the marble, some beds of which are of good quality, are beds of impure limestone and shale, which make up a considerable part of the formation in this belt. Openings have been made on the belt four miles northwest of Knoxville and near Ebenezer, but no quarries are being operated at the present time.

*The Galbraith Belt.*—The Galbraith Belt begins at Mooresburg in Hawkins County and extends northeast into Virginia. It is bounded on the southeast by the Clinch Mountain fault, to which it bears the same relation that the Black Oat Belt does farther southwest. As it lies in the trend of the same fold to which that belt owes its existence, the two belts might with some propriety be regarded as constituting one belt.

In this belt the marbles occupy an intermediate position in the formation, being underlaid by the characteristic Lenoir limestones, while similar limestones and shales intervene between the marbles and the next formation above, which, in this region, is called the Moccasin formation. The marble occurs in massive layers and is mostly dark red or chocolate in color. In places the rock becomes splashed with white, these areas representing the crystalized remains of the shells or other hard parts of animals. The faces of the slabs thus often present attractive and sometimes fantastic patterns, due to the manner in which these masses have been cut by the saw. A special variety of this kind is called the "Dolly Varden" marble. Both pink and gray marbles occur, but they have not been worked, owing to the greater accessibility and demand for the red varieties.

The disturbance in the beds has been great, resulting in the complete overturning of the strata toward the northwest. As a result of this the beds have an overturn dip of nearly 60 degrees toward the southeast, bringing the Knox dolomite above the marble. The Clinch Mountain fault passes close to the south side of the belt, bringing the Rome formation upon the Knox dolomite, representing a horizontal displacement of not less than three miles.

A large number of quarries have been opened in this area, some of the oldest quarries in the State being located on this belt. One of the first to be worked was the Galbraith (or National) quarry, near Moccasin Bend, from which was obtained the marble used in the construction of the United States Capitol Building at Washington, D. C. The

history of the beginning of the marble industry is given in Safford's Geology of Tennessee, pp. 508, 509. At the present time, the Stamps Quarry, near Galbraith Springs, is the only one in operation.

*The Concord Belt.*—This, the third belt of the series, makes its appearance near Sweetwater and extends northeast past Loudon, Lenoir City, Concord, and through the northern part of Knoxville, ending near Straw Plains in a closed loop approximately four miles in diameter. Just west of Knoxville marble is missing in this belt, due evidently to non-deposition. In general, the proportion of impure earthy beds is less in this belt than in the Luttrell and Black Oak Belts, while the thickness of the marble becomes proportionately greater, a feature apparently due to its position nearer the middle of the marble basin. Moreover, the marble beds occur higher in the formation, for the most part at the top. The Lenoir beds at the base have a greater thickness than farther westward, while those overlying the marbles are much diminished in thickness, or absent altogether. As in the case of the Luttrell Belt, the proportion of shale increases northeastward, being especially noticeable between McMillan and Straw Plains.

Quarries have been opened on this belt at many points from Loudon northeast to McMillan, but most of the output has come from the vicinity of Concord and Knoxville. The belt is closely paralleled throughout its course by the Southern Railway and by the Tennessee River, which intersects it at a number of places, being thus especially favored as to transportation facilities.

Sloan's quarry, from which most of the marble used in the State Capitol at Nashville was taken, is located o nthis belt two miles north of Knoxville, and near the Southern Railway. This marble is highly variegated and resembles more nearly that from the Hawkins County quarries, from which it differs in being a deeper red and less delicately shaded. It was used in the State Capitol of Ohio for ornamental work. The quarry was opened in 1852, and its product, with that from Hawkins County, was for many years, and to many people still is, the only "Tennessee marble." Of late the demand is for a uniformly warm, bright-tinted stone, such as the granular gray, and pink beds, which underlie the variegated fossiliferous variety, and found in better development in the adjoining belt. This once famous quarry has been idle many years.

*The Knoxville Belt*—The Knoxville Belt, which is at present economically one of the most important of the marble areas, makes its appearance several miles southeast of Sweetwater in Monroe County, and extends northeast to the vicinity of Ruggles Ferry, on the Holston River. A small detached outcrop of this belt appears at the northern

base of the Red Knobs, five miles southeast of Sweetwater. A beginning was made at one time to quarry these beds at what was called the Craighead Cave Quarry, but differences in the management led to the abandonment of the project.

At the northeastern and southwestern extremeties of the belt the rocks dip toward the southeast at an angle of about 30 degrees with the horizontal surface. In the vicinity of Louisville the dip is diminished. Owing to this change of dip the width of outcrop varies considerably, the notable expansion in the vicinity of Louisville being directly due to the flattening of the beds in this locality.

In this and the French Broad Belts the marble formation is on the whole more uniform in bedding, due apparently to location near the middle of the marble basin, and hence freedom from the incursion of argillaceous sediments. The operations on this belt, which at the present time exceed those of any other area, extend from Meadow Station, on the south, to Boyd's bridge, on the north. In this portion of the belt there are twelve quarries in active operation, while there are a number of others which have been temporarily or permanently discontinued.

The leading variety of marble found in this belt is the pink, one of the most beautiful and popular shades produced in this country.

In addition to the pink, which is found in most of the quarries of this belt, some quarries are noted for their chocolate colors, while others make a specialty of gray colors. Owing to differences in the conditions of sedimentation, the character of the beds vary from place to place, and hence each quarry has some distinguishing feature in the variety of its product. There has been much progress made in the development of this area during recent years, a growth that is destined to continue, as the deposits are of good quality and of vast extent.

*The French Broad Belt.*—This belt, the next in order toward the southeast, is U-shaped, with open end toward the northeast, and the western limb crossing the river at the junction of the French Broad and Holston. Its shape is due to the planing off by erosion of a fold, whose axis pitches toward the southwest. Between this and the Knoxville belt is a synclinal trough, which is occupied by rocks of the Tellico and Sevier formations. Hence the rocks of the northwestern limb dip toward the northwest, while those on the southeastern side of the fold resume their usual southeastern dip. The marble pinches out in the vicinity of Riverdale on the French Broad, which marks approximately the limit in this direction of the basin in which the materials of the marble were deposited. Originally the marbles were

connected over the dome of the fold, their absence in this area now being due to erosion.

Owing both to favorable conditions for quarrying and transportation facilities, operations on this belt have been most active in the vicinity of the forks of the river. The new K. S. & E. Railroad crosses portions of the belt toward the southwest, and will doubtless promote operations in that portion of the field.

*The Bays Mountain Belt.*—This, the most southeasterly of the marble areas, lies along the north side of Bays Mountain in the south part of Knox County and extends southwest for a short distance into Blount County. The belt has its greatest width in the vicinity of Neuberts, where it divides into three branches, which continue to diverge until terminated in the vicinity of Rockford.

Three prominent faults occur in the vicinity, which, like nearly all the faults of the Great Valley, are what are known as thrust faults, the strata on the southeast being thrust over upon the rocks on the northwest side of the break. The fault plane dips at a relatively high angle toward the southeast. The most northerly of the faults makes its appearance on the French Broad and continues with little abatement in strength into Monroe County, a distance of over fifty miles. To this fault is due the outcrop of marble one and one-half miles east of Meadow Station, on the Louisville & Nashville Railway, on which are located the quarries of the Meadow Marble Company.

Owing to lack of transportation facilities, no attempt has hitherto been made to develop the Bays Mountain Belt. Such facilities are now afforded by the newly constructed Knoxville, Sevierville & Eastern Railroad, which crosses the belt in the vicinity of Neubert Station, and efforts will doubtless be made to develop the area. No information is at present available concerning the character of the marble and the conditions for development in this belt.

## CHARACTER OF THE MARBLES.

*The Holston Marble.*—The Holston marble beds vary considerably in character, both in their horizontal and vertical extent, due to differences in the character of the sediment at the time of its deposition. Carbonate of lime, iron oxide and clay were deposited together along with shells of large and small mollusks, and the hard parts of crinoids and other invertebrate animals. The firmness of the rock depends upon the large proportion of the lime contained, while the dark rich colors are due to the oxide of iron. But, if the iron be present with the clay in large proportions, the rock becomes a worthless shale. The colors vary from cream, yellow, brown, chocolate, red and pink to gray or blue in endless variety. The leading varieties are the pink, gray and

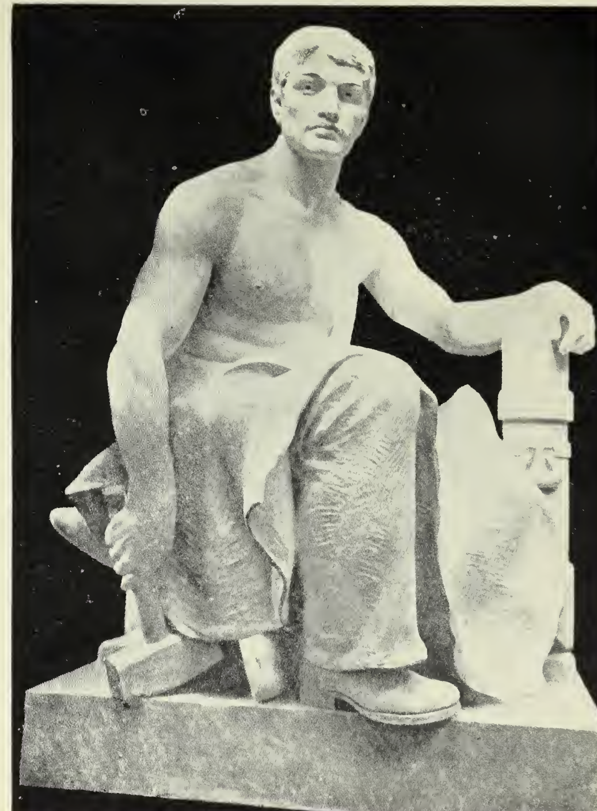


PLATE III.

A. and B. Statues, Carved From Tennessee Marble, at the Quarry of the Ross and Republic Marble Company, by Peter Rossak; J. Messey Rhinet, Sculptor.

chocolate (or cedar) and variegated, and each quarry has its own distinctive shade in one or more of these colors.

The colors are either scattered uniformly throughout the rock or occur in aggregations or patches, sometimes presenting a highly variegated appearance. The forms of fossils sometimes appear as crystals or patches of crystals of pure white calcite. In some of the beds the curious and fantastic arrangement of the colors constitutes one of the chief beauties of the marble. Like the shaly matter, the iron oxide is an impurity, and the two are apt to accompany each other. Formerly the most prized color was the variegated, in which there is a balance between the pure and the impure, a condition which often takes place locally, and slight changes in the character of the sediment may result in deterioration or in better quality. Such changes are common in most sediments and must be expected in quarrying the marble. Not only may a good bed become poor, but a poor bed may develop into good marble. (a) Owing to their adaptability to use in monuments and other structures requiring purity and evenness of texture and coloring, the lighter shades of pink and gray have of late years won deservedly high recognition in various centers, and are now the most popular varieties.

The dynamic movements, to which the rocks have been subjected since their consolidation, has resulted in more or less tilting of the strata and in fracturing, and in places in crushing of the beds. The available localities for quarrying are limited by these conditions. The best situations are where the strata dip at small angles and hence cover a larger surface. Where the strata are more folded and dip at higher angles, less stripping may be required, but deeper cutting is necessary for prolonged quarrying. There are many localities in which, owing to these or other adverse conditions, development is now retarded. In time the marble in these areas will become available as the more favorable localities are exhausted.

Owing to its soluble nature, the impure marble is either completely unaltered and fresh, or wholly reduced to red clay. As solution extends down along fractures in the stone, the surface of the rock is deeply pitted or covered with knobs and pillars of the unaltered marble. Filling the depressions is a deep red clay derived from the marble as a result of decomposition. These solution spaces are numerous in the surface beds and often extend down as holes and caves into the underlying rock, to the annoyance of the quarryman. Alteration does not affect appreciably the pure marbles, these being as solid at the surface as at great depths. The impure marbles, which are shaley at

*a.* Folio No. 16, Knoxville, U. S. Geological Survey, 1895, p. 6.

the surface, appear solid on going down; but when sawed and exposed to the weather, their inferiority appears in splits along the argillaceous seams and in cracks through the thicker masses.

At varying distances across the face of a polished slab of marble may be seen irregular bands of gray or black, which close inspection resolves into a suture line, *stylolites,* the *"crowfoot"* of the quarryman. These represent original bedding planes, the interpenetration having been effected probably by pressure when the sediments were still soft. To these accidents of structure is due much of the beauty of some of the gray and pink marbls. Affecting the quarry beds to a greater or less extent are discontinuous cracks, known as "cutters." They consist of fine cracks, usually recemented by secondary calcite, which extend outward from solution channels to varying distances into the rock. The stone tends to break more readily along these planes, while solution takes place more rapidly here than elsewhere. They are evidently connected in origin with the main joints or fractures, and from their relation to these, and the weathered surface, it seems probable they owe their origin to the strains set up in the rock by weathering processes. If so, then they should diminish with distance from the weathered surface, and that such is the case is maintained by quarrymen. In few places, however, has quarrying proceeded far enough to offer satisfactory evidence on this point.

Tests for the absorption of water show the purer marbles to have high resistance, a character of importance as fitting it to resist weathering and also making it impervious to stains and dirt. A non-absorbent stone, when washed, appears white and clean, while a porous stone soon fills with dirt and smoke and can never again be made to appear as at first. Tennessee marble is practically impervious to stains, and this fact, together with its strength, durability, variety and beauty, gives it special favor with contractors and builders.

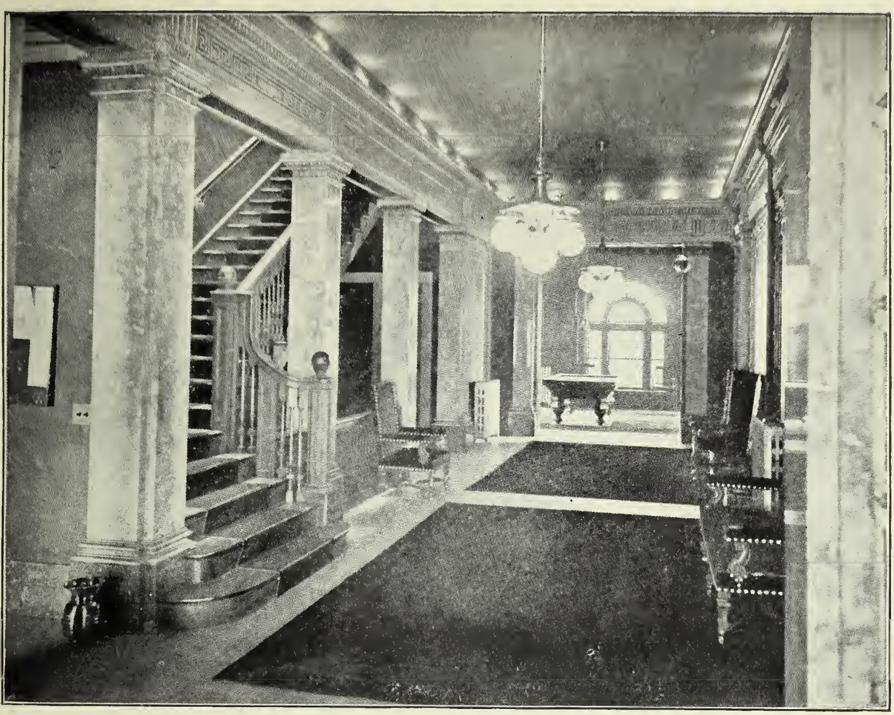
An absorption test on gray marble from the Meadow quarry made in the Sheffield Scientific Laboratory by George S. Jamieson, gave the following results.

ABSORPTION TEST ON GRAY MARBLE.

| No. | Weight (Dry) | Weight after absorption | Difference | Percentage absorbed | Ratio |
|---|---|---|---|---|---|
| I | 1,428.00 g | 1,428.10 g | .10 g | .007 | 1—14,280 |
| II | 1,424.00 g | 1,424.10 g | .10 g | .007 | 1—14,240 |

The test pieces were submerged 45 hours.

PLATE IV.



A. Tennessee Marble in Interior Finish of Cumberland Club Building, Knoxville.

B. Blocks of Tennessee Marble Too Large for Freight Cars.

Tennessee marble is a very compact stone, and in practical tests has demonstrated its adaptability for uses requiring great burden-bearing strength. Of the total marketed product for 1908, 34.18 per cent was devoted to rough building purposes. Tests thus far made of the crushing strength of the Tennessee marbles indicate great resistance, but, inasmuch as the size of the cubes used in the different tests differed, the results are not of much value for purposes of comparison. A series of tests with standard two-inch cubes is contemplated, the results of which will appear in the forthcoming bulletin. The first volume of Kidder's Building Construction and Superintendent gives the following results of tests said to have been conducted by Merrill and others.

| | Crushing strength per cubic inch | Ratio of absorption |
|---|---|---|
| Pink Tennessee | 15750 lbs. | 1-12000 |
| White Tennessee No. 1 | 17212 lbs. | 1-12400 |
| White Tennessee No. 2 | 14812 lbs. | 1-14800 |
| Dark Pink Tennessee | 13750 lbs. | 1-10700 |

The Ordnance Department, United States Army (Watertown Arsenal), tested three cubes of "Meadow Grey" on March 25, 1908, on the United States testing machine. Their report is as follows:

"TESTS BY COMPRESSION—TEST NO. 13752.

| Height Inches | Dimensions Compressed Surface Inches | | Section area Square inches | First crack Pounds | Ultimate Strength Total Pounds | Per cubic in. Pounds |
|---|---|---|---|---|---|---|
| 3.99 | 3.98 | 3.99 | 15.88 | 293,000 | 312,000 | 19,650 |
| 3.97 | 3.96 | 3.96 | 15.68 | 320,000 | 327,000 | 20,850 |
| 3.98 | 3.98 | 3.98 | 15.84 | 289,900 | 289,800 | 18,300 |

Correct. (Signed) J. E. HOWARD.

C. B. WHEELER, Major Ordnance Dept., U. S. A., Commanding."

With standard two-inch cubes the results would be lower.

According to Merrill the weight of Tennessee marble is 180 pounds per cubic foot, which is some 14 pounds heavier than granite.

Chemical analyses of the pink and gray varieties show these to be composed almost wholly of calcium carbonate.

ANALYSES OF TENNESSEE MARBLE.

| | No. 1 | No. 2 |
|---|---|---|
| Calcium oxide ($CaO$) ................ | 55.12 | 55.87 |
| Magnesium oxide ($MgO$) ............ | 0.51 | 0.15 |
| Carbon dioxide ($CO_2$) ................ | 43.98 | 43.47 |
| Iron Oxide ($FeO$, $Fe_2O_3$) ........... | 0.21 | 0.08 |
| Alumina ($Al_2O_2$) .................... | .... | 0.16 |
| Silica ($SiO_3$) ........................ | .... | 0.23 |
| Insoluble residue ..................... | 0.07 | .... |
| | 99.89 | 99.96 |

No. 1.—Holston marble taken from a quarry near Knoxville. Analysis made in the laboratory of the Tennessee Experiment Station, University of Tennessee.

No. 2.—Gray marble from the Meadow fuarry. George S. Jamieson, Analyst, Sheffield Scientific School, Yale University.

Expressed in terms of the rational formula the composition would be:

| | No. 1 | No. 2 |
|---|---|---|
| Calcium carbonate ($CaCO_3$) ........... | 98.64 | 99.20 |
| Magnesium carbonate ($MgCO_3$) ....... | 0.97 | 0.29 |
| Iron oxide ........................... | 0.21 | 0.08 |
| Alumina ............................. | .... | 0.16 |
| Silica ................................ | .... | 0.23 |
| Insoluble residue ..................... | 0.07 | .... |
| | 99.89 | 99.96 |

The rock burns well for lime, the Tennessee Producers Marble Company disposing of the waste of its quarry near Knoxville for that purpose. At the Luttrell quarry some beds are quarried especially for burning into lime in kilns near by. The composition of the rock shows it to be well adapted for the manufacture of Portland cement, and given a supply of shale, suitably located conditions would be present for the establishment of a profitable industry. It is believed these conditions exist in the vicinity of Knoxvile.

## MARBLE QUARRYING IN EAST TENNESSEE.

*Historical.*—Within the last few years "Tennessee" marble, the name by which the Holston marble is generally known, has come more and more into favor with sculptors, who frequently specify it for the most expensive and artistic work. It is often shipped in large blocks to the studios of the artists, but it is found more satisfactory in some cases for the artists to select their material in the quarry, set up their studios and turn out their figures on the grounds. One marble company has

PLATE V.

MARBLE QUARRY NEAR KNOXVILLE.

a shop in connection with its plant, where sculptors of New York and Italy have produced some handsome groups of statuary for noted buildings in this country. (See Plate II.)

According to Safford (a) marble quarrying began in East Tennessee in 1838 with the organization of the Rogersville Marble Company, with headquarters and works at Rogersville in Hawkins County. The stone was first brought prominently to public attention by its adoption for interior decoration of the United States Capitol Building at Washington. Stone for this purpose was obtained from quarries opened by the government on the banks of the Holston about nine miles southwest of Rogersville. These were located on the old Galbraith property and were known for many years as the National Quarries. For many years the entire supply of the so-called "Tennessee Marble" was drawn from quarries in this vicinity, but of late years, owing to the more easy accessibility of the stone in Knox and Blount counties, together with the growing demand for the pink and gray granular over the variegated varieties, there has been a decided change, and the quarries of Hawkins County produce but a relatively small proportion of the entire output, as shown by the statistics at the end of this report.

*Operators*—Mention only can be made here of the quarries of the district. Detailed description will appear in the more complete report under preparation. Although the effort is made to include all operations now in progress, the time available has not been sufficient for an exhaustive study of the district, and some quarries may be overlooked.

*The Appalachian Marble Company*—This company, organized in 1911, with offices at the intersection of the Middlebrook and Lonsdale car lines, will operate what is known as the Stinette quarry, located on the Knoxville Belt 8 miles below Knoxville and 2 miles from Lyons View. Pink and darker shades of marble occur in the quarry. The quarry is now being opened preparatory to active operations. Five drills and two Ingersoll channelers will be used and about 50 men employed in the quarry.

This company has also recently come into possession of what is known as the Tadpole quarry located on the French Broad Belt within and close to the forks of the Holston and French Broad rivers. Active operations will be undertaken in this quarry also according to present plans.

*a.* James M. Safford, Geology of Tennessee, p. 508.

*The John J. Craig Company*—This company operates two quarries in Blount County, one, the Crisp quarry, 1 miles east of Kiser Station on the Louisville and Nashville Railroad, the other about 2 miles northeast of Friendsville on the same road. Both are situated on the Knoxville Belt.

In the Crisp quarry the marble now quarried is the cedar and variegated. Pink marbles occur at lower levels, but they have not been developed. In the quarry near Friendsville the marble is mostly pink. The chief output of the company comes from this quarry, 9 steam drills and about 45 men being employed.

*Evans Marble Company*—This company operates what is known as the Godfrey quarry located in the forks of the Holston and French Broad rivers on the French Broad Belt, and the Evans quarry located about 1½ miles northeast of Friendsville on the Knoxville Belt in Blount County. Pink marbles constitute the chief output of these quarries, but fine gray marble is obtained from the Godfrey quarry, and some cedar from the Evans quarry. About 305 men are employed in both quarries.

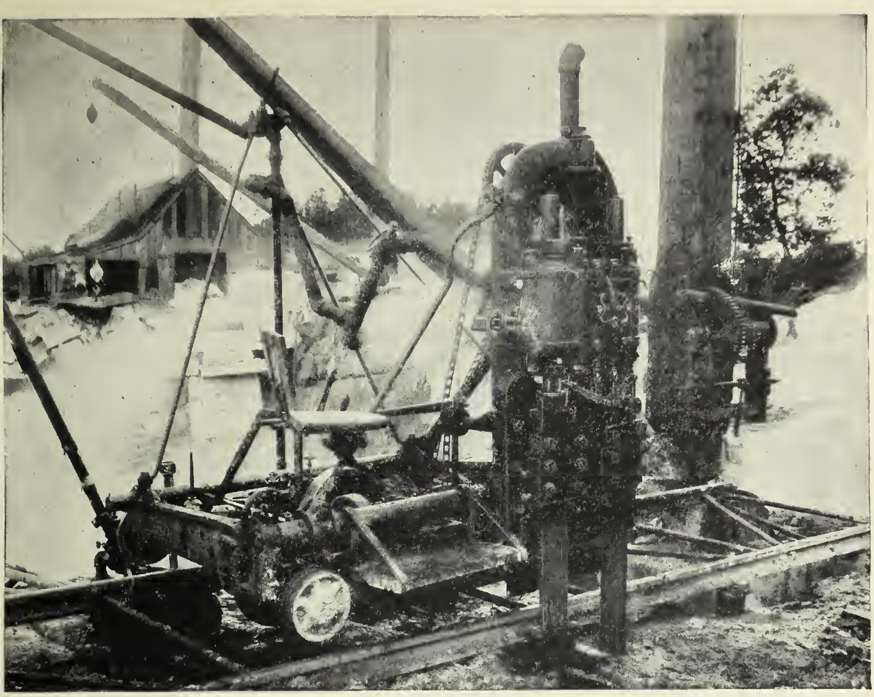
*T. S. Godfrey Marble Company*—This company operates two quarries located on the French Broad Belt above the forks, one the Hercules near Asbury, the other just east of the Gray Eagle quarry. The marble beds have a thickness of over 75 feet, the lower beds being pink and the upper gray. Eight channeling machines are used and 20 drills. From 100 to 110 men are employed about the quarries.

*Gray Eagle Marble Company*—This company operates the Gray Eagle quarry, located in the forks of the Holston and French Broad rivers on the French Broad Belt not far from the Godfrey quarry. Pink marble constitutes the chief output. One channeler and twelve drills are operated here. The number of men employed in the quarry is 60.

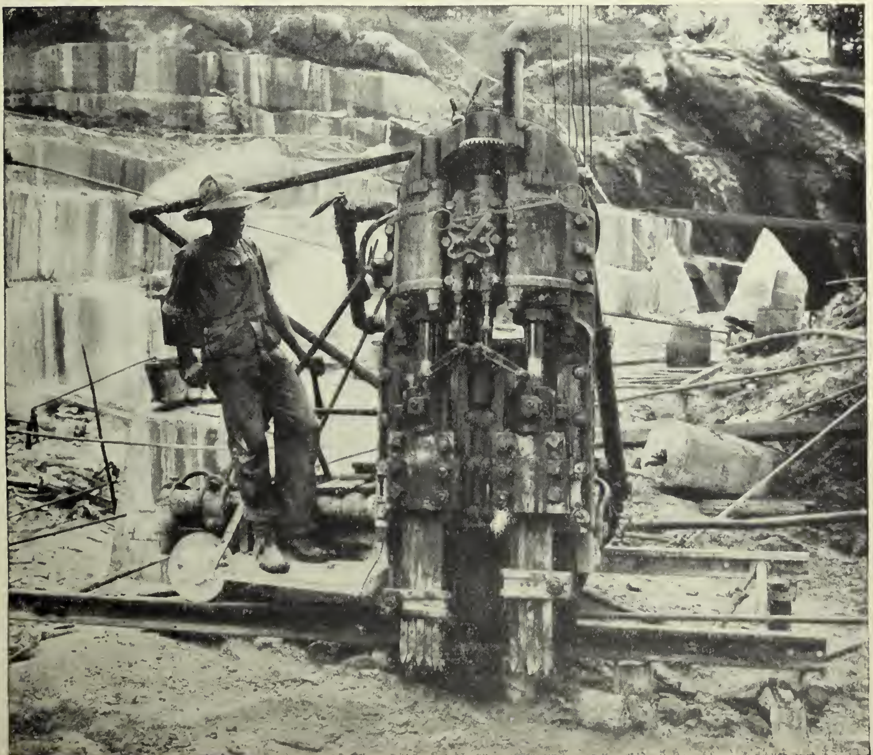
*Graystone Marble Company*—This company owns what is known as the old French quarry, located on the south outcrop of the French Broad Belt, about 3 miles above the forks of the river. The marble is mostly of the pink variety, but there is some gray, and some of the higher beds are chocolate or cedar.

*Imperial Marble Company*—The quarry is located on the Southern Railroad, near the border line between Knox and Loudon counties. The marble is of the pink and gray varieties. No operations are being conducted by this company at the present time.

*Knox Marble Company*—The Knox Marble Company operates a mill and quarry located on the Island Home Pike about a mile northeast of the south end of the county bridge. The quarry is located on



A. The Sullivan Duplex Channeler, in the Quarry of the Evans Marble Company, near Friendsville, Tenn.



B. Duplex Channeler, Same Quarry, Raised From Rails to Permit

the Knoxville Belt near the mill. Light and dark pink varieties are found in the quarry. The quarry was opened only recently and has not reached its full working capacity. About 20 men are employed in the quarry.

*Knox Marble and Railway Company*—Two quarries are operated by this company, both on the Knoxville Belt, one in Blount County ½ mile east of Carpenter Station on the Louisville and Nashville Railroad, the other in Loudon County about a mile south of McMullens Station on the Louisville and Nashville Railroad. The first, known as the Founk quarry, supplies a pink marble. The second, known as the Alexander quarry, is located on ledges of pink marble near the base of the formation. The stone shades from light pink to medium and darker shades. Cedar marble is said to occur in higher beds which outcrop at higher levels in the adjoining hills. Blocks from this quarry were used for the entrance to the New York Library.

One channeling machine and five steam drills are used here.

*Meadow Marble Company*—The company operates one quarry located 1½ miles northeast of Meadow Station on the Louisville and Nashville Railroad. Gray marble constitutes the chief output of the quarry, though some pink marble is also found here. Two Sullivan channelers and 7 steam drills are in use in this quarry. About 35 to 50 men are employed in the quarry, but it is said 100 could be employed if the men were available.

This quarry is located on a small outcrop which owes its existence to a fault which extends northeast past Rockford to the French Broad River. The stone from this quarry is worked up in the mill of the Cumberland Marble Mill Company, situated on the premises. The quarry was opened in 1906.

*Quaker Marble Company*—The company operates the Crawford quarry, located ½ mile east of Friendsville, on the Knoxville Belt. Two shades of pink marble are found in this quarry, while cedar marble occurs in the upper part of the opening; but the last named beds are of poor quality.

One channeler and 4 steam drills are used in this quarry. About 25 men are employed, the monthly output being about 1,000 cubic feet.

*The Ross and Republic Marble Company*—This company was formed by the consolidation of the Ross Marble Company and the Republic Marble Company. The Ross quarry is located on the French Broad Belt, 4 miles northeast of Knoxville, on the south side of the river. Both gray and pink marbles are found in this quarry, the gray above and the pink below. Six hundred feet north of the quarry is the mill operated by the same company, in

which the stone rough-dressed in the quarry is prepared for the market. Ten steam drills and three channelers are used in the quarries, and about 40 men are employed. Most of the output of the quarry goes to the mill for dressing, though some large blocks are shipped rough-dressed to eastern markets. The Republic quarry is located 1 mile north of Luttrell, Tenn., on the Luttrell Belt. The beds worked here occur near the base of the formation, and consist of two main ledges, the upper of which consists of light chocolate or "cedar," much esteemed for interior decoration, while lighter shades, including pink, come from lower beds. Beds of gray marble come in at higher levels, and are quarried about a quarter of a mile south of the marble quarry for lime.

*John M. Ross*—John M. Ross operates a quarry on the French Broad Belt 3½ miles northeast of Knoxville and about ¼ of a mile south of the Crawford quarry. Light pink and gray marbles are found here, the former constituting the chief output. This quarry has been operated about 8 years, the largest opening having a depth of about 70 feet. Five steam drills and three channelers are in use in this quarry and 30 men employed.

*Royal Marble Company*—This is a new company formed in 1910, which is opening a quarry on the French Broad Belt 4 miles southeast of Knoxville. It is reached by a short spur from the new Knoxville, Sevierville and Eastern Railroad, called the Kincaid Spur. Specimens from this quarry of a highly variegated marble of dark red and white were exhibited at the Appalachian Exposition in 1910 and attracted much attention. They are in the collections of the survey at Nashville. Other varieties occur here and will be worked when the quarry has been sufficiently opened.

*H. B. Stamps*—The mill and quarry of H. B. Stamps are on the Galbraith Belt at Galbraith Springs in Hawkins County. The principal varieties quarried here are different shades of cedar, variegated marbles and some pink. No gray marble is produced, though some beds of this variety occur here. Most of the output of this quarry is worked up in the mill, located on the property, for furniture. Some is shipped unfinished. Some blocks from this quarry are now in preparation for decorating the Wisconsin State Capitol.

One-half mile west of the Stamps quarry, at a depression or saddle in the crest of the ridge, are two old quarries: the Stamps Star quarry and the Evans quarry, in both of which work was abandoned ten years ago. The old Galbraith quarry is about 1½ miles northeast of the Stamps quarry, and a number of others now idle occur along this belt.

*Tennessee Producers Marble Company*—Two quarries are being op-

erated and a third is in process of development. The Hackney quarry, 1 mile east of Friendsville, has been recently discontinued, as has also another quarry ½ mile east of McMullens Station in Blount County.

The Bond quarries are located in the bend of the river on the Knoxville Belt, 4 miles south of Ebenezer, and a like distance east of Concord. These are among the oldest producing quarries of this section, having been in operation for 25 or 30 years. Seven pits have been opened and worked at various times. These range in depth from 25 to 100 feet. This quarry produces an attractive pink marble called the "Bond Pink," which is very popular with the patrons of the company. The blocks taken from the quarry are trammed ¼ mile to the bank of the river, loaded on barges and floated to Knoxville. There they are loaded on cars and taken to the company's mill in the northwest part of the city. Most of the available marble has been taken from this quarry, and the company is preparing to develop other of its extensive holdings of marble properties.

The McMillan quarry, owned by the Tennessee Producers Marble Company, is located on the Knoxville Belt on the north side of the Tennessee River about 1 mile northeast of the county courthouse in Knoxville. The specialty of this quarry is a gray marble, but pink is found here also, though it is not worked. Four pits have been opened on this property, and preparations are making to open a fifth. The deepest of the workings is about 100 feet. The pit now being operated is about 75 feet deep. Four channeling machines and four steam drills are in use at the present time. The number of men employed here varies from 50 to 60.

The Dunlap quarry is a new quarry being opened by the Tennessee Producers Marble Company, about 2 miles southeast of Friendsville, in Blount County.

The Hackney quarry, recently abandoned, is located 1 mile east of Friendsville. The rock here shows light pink, with some beds of gray.

The McMullen quarry is located about ½ mile east of McMullens Station, in Blount County. The stone here is mostly a dark cedar, with some pink in the lower part of the workings. Work in this quarry has been discontinued.

*The Victoria Marble Company*—This company operates the Victoria quarry, located on the Knoxville Belt, 6 miles northeast of the city, near Boyd's bridge over the Holston River. The chief output consists of pink marble, which is taken from a series of beds aggregating 60 to 75 feet thick. These beds occur near the base of the formation, and are overlaid by a bed of impure gray marble too hard for use. Above this is a light pink marble upon which no work has been done. As

there promises to be considerable demand for the lighter shade, the company is preparing to develop these beds in the near future. Two channelers and 8 steam drills are used.

The product of the Victoria workings is all shipped rough-dressed, and is in much demand in some of the large cities for monuments, entrances and other parts of fine buildings where a stone of fine quality is desired. This company has recently filled a contract with the Canadian Government for the Baldwin-Lafontain Memorial to be erected at Ottawa, Canada.

## MARBLE MILLS.

Brief mention only can be made here of the marble mills in operation in the region. In some cases the stone is sold direct from the quarry in blocks. Some mills confine their operations to sawing and rubbing, but in most of the mills provision is made for polishing and finishing in any desired form. Some companies employ a full staff of marble architects, and are prepared to undertake contracts for the erection of almost any kind of structural work.

*Appalachian Marble Company*—The mill of the Appalachian Marble Company is located at the intersection of the Middlebrook and Lonsdale car lines. This is a new mill and has not received its full equipment. It is provided with eight gang-saws and two rubbing beds. A finishing machine is to be added later. The mill will employ about 50 men, and the estimated output will be about 75,000 cubic feet of marble per annum.

*Cumberland Marble Company*—The mill of the Cumberland Marble Company is at the quarries of the Meadow Marble Company, 1½ miles northeast of Meadow, Blount County, Tennessee. The mill is designed primarily to care for the output of the Meadow quarries. It is equipped with four gang-saws, two rubbing beds, two finishing tables, two polishing tables, one air compressor and five pneumatic tools. The output is about 7,500 square feet of finished (¾-inch) marble, and 12,500 square feet of sawed slabs and tile per month. Thirty-five men are employed in and about the mill.

*Empire Marble Company*—The Empire Marble mill is located in West Knoxville at the intersection of the Southern and Louisville and Nashville railroads. The operations of the mill are confined chiefly to the output of the quarries of the Gray Eagle and John J. Craig quarries. The mill is equipped with ten gang-saws, three planers, three rubbing beds, three diamond saw machines, two moulding machines, and four finishing machines. Seventy-five men are employed in and

PLATE VII.


Mill of the Evans Marble Company, Knoxville, Tenn.
One of the largest mills in the United States.

around the mill, and the output is about 43,000 square feet of finished ⅞-inch marble per month.

*Evans Marble Company*—The mill of the Evans Marble Company is situated on Dameron Street, adjoining the Southern Railroad in north Knoxville. The plant comprises three large buildings (Plate VII), covering 400,000 square feet of space, and has a capacity of about 1,800 to 2,000 square feet of finished ⅞-inch marble per day, or 40,000 to 45,000 square feet per month. The mill is equipped with twenty-six gang-saws, nine rubbing beds, five planers, and eight finishing machines. The company employes 425 to 450 men in its quarries and mill, of which number 125 are employed in and about the mill.

*Knoxville Marble Company*—The mill of the Knoxville Marble Company is situated on the south side of the river on Island Home Pike about 1 mile above the county bridge. It is connected with the Southern Railroad by a spur. The mill is owned and operated by John M. Ross and J. T. Kelly. Its equipment consists of eight gang-saws, three rubbing beds and two finishing machines. The building is 75 by 250 feet in area, and 15 to 20 men are employed in and about the mill. About 3,000 cubic feet of block marble is worked up each month.

*The Ross and Republic Marble Company*—This company operates two mills, one located at the Ross (Crawford) quarries 4 miles north-east of Knoxville, and the other at the quarries near Luttrell. The first or Ross mill consists of a frame building 75x300 feet equipped with six gang-saws, one planer, two rubbing beds and one polishing machine. Twenty-five men are employed, three of them on the night shift.

The mill at Luttrell is located at the quarries, and is equipped with six gang-saws and two rubbing beds. No finishing is done here, the entire product of the quarry being sold in the rough or sand-rubbed only. From 5 to 7 men are employed in the mill.

*Stamps Marble Mill*—The mill of H. B. Stamps is at the quarry, on the banks of the Holston River near Galbraith Springs. It is equipped with six gang-saws, one rubbing bed and two finishing machines. Twenty-five men are employed in quarry and mill. Most of the output is of finished marble for use in furniture. The average output is about 3,500 square feet of finished marble per month.

*Tennessee Producers Marble Company*—The mill of the Tennessee Producers Marble Company is located on University Avenue adjacent to the Louisville and Nashville Railroad and the Lonsdale car line. The equipment of the mill consists of 25 gang-saws, 9 rubbing beds,

2 planers, 1 diamond saw machine, 2 moulding machines, and 6 finishing machines. About 125 men are employed in and about the mill, and the average output is from 40,000 to 50,000 square feet of finished ⅞-inch marble per month.

*United States Marble Company*—The mill operated by this company is located at the riverside below Knoxville near the University farm. The building is 80x130 feet in size, and is equipped with eight gang-saws and two rubbing beds. No finishing is done in this mill. Ten men are employed in and about the mill. No quarries are at present operated by this company, the mill being devoted exclusively to custom work.

## LIST OF MARBLE COMPANIES AND THEIR OFFICERS.

| *Company* | *President* | *V. President* | *Sec'y and Treas.* | *General Manager* | *Headquarters* |
|---|---|---|---|---|---|
| The Appalachian Marble Co. | S. F. Kries | Jno. A. Kries | Thos. J. Dean | Jno. A. Kries | Knoxville. |
| The Jno. J. Craig Co. | J. B. Jones | S. A. Rogers | Jno. J. Craig | J. B. Jones | Knoxville. |
| Cumberland Marble Mill Co. Meadow, Tenn. | C. N. Marthens (and Treas.) | H. D. Cheney | Henry McCoskie, Sec'y | Henry McCoskie | Chicago, Ill., 804 Association Bldg. |
| Empire Marble Co. | J. B. Jones | H. Kries | W. R. Monday | J. S. Stone | Knoxville. |
| Evans Marble Co. | W. H. Evans | Chas. R. Evans | E. M. Wellener | E. N. Willard | Baltimore, Md. |
| T. S. Godfrey Marble Co. | ........ | ........ | ........ | J. E. Willard | Knoxville. |
| Gray Eagle Marble | Harmon Kries | W. R. Monday | J. B. Jones | ........ | Knoxville. |
| Graystone Marble Co. | E. T. Sanford | ........ | J. Eckels | J. Eckels | ........ |
| Imperial Marble Co. | Daniel Briscoe, Sr. | G. L. Price | J. L. Kincaid | W. A. Doughty | Knoxville. |
| Knox Marble & Railway Co. | J. McF. Carpenter | James Welcker | John Knox | John Knox | ........ |
| Knoxville Marble Co. | Jno. M. Ross | J. T. Kelly | ........ | ........ | ........ |
| Meadow Marble Co. | T. S. Godfrey | Geo. E. Mills | E N. High | ........ | Cincinnati, O., 516 1st Nat. Bk. Bldg. |
| Quaker Marble Co. | Frank Dullam | Homer Day | L. G. Goodenough | L. G. Goodenough | Flint, Mich. |
| The Ross & Republic Marble Co. | Frank S. Meade | E. S. Winslow | Chas. Seymour | E. S. Winslow | Knoxville. |
| Jno. M. Ross | ........ | ........ | ........ | ........ | Knoxville. |
| Royal Marble Co. | John Kern | ........ | John Kern | John Kincaid | ........ |
| H. B. Stamps | ........ | ........ | ........ | ........ | Galbraith Springs. |
| Tennessee Producers Marble Co. | ........ | M. S. Spaulding | C. E. Randall, Sec'y C. R. Morse, Treas. | B. L. Pease | ........ |
| United States Marble Co. | J. M. Muller, Jr. | Chas. J. Boeh | W. P. Miller | W. P. Miller | Knoxville. |
| Victoria Marble Co. | J. W. Starkweather | Robt. B. Starkweather | Robt S. Starkweather | J. W. Starkweather | Knoxville. |

## PRODUCTION

The total value of marble produced from Tennessee quarries in 1909, as shown by the report of the Chief Mine Inspector, was $590,585, as compared with $761,222 in 1908 (a). The following figures concerning the marble production of the State in 1909 are taken from the report of the State Mine Inspector:

VALUE OF MARBLE PRODUCTION IN TENNESSEE, IN 1909, BY USES.

| COUNTY | Total Average Number of Employes | Rough | | | Dressed | | | | Grand Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Building | Monumental | Other Purposes | Building | Monumental | Interior Decoration | Other Purposes | |
| Blount | 211 | $------- | $----- | $ 15,640 | $ 1,579 | $----- | $134,392 | $----- | $151,611 |
| Hawkins | 20 | -------- | ------ | -------- | 1,050 | ------ | -------- | 5,250 | 6,300 |
| Knox | 547 | 48,000 | 4,625 | 12,175 | 10,000 | 4,275 | 310,795 | ------ | 389,870 |
| Loudon | 20 | -------- | ------ | -------- | -------- | ------ | 9,104 | ------ | 9,104 |
| Union | 50 | -------- | ------ | 22,500 | -------- | ------ | 11,200 | ------ | 33,700 |
| Total | 848 | $ 48,000 | $4,625 | $ 50,315 | $ 12,629 | $4,275 | $465,491 | $5,250 | $590,585 |

RECAPITULATION

| | | |
|---|---|---|
| Total average number of employes | | 848 |
| Average wages paid per day | $ | 1.40 |
| Total amout paid for labor | $ | 306,387 |

PRODUCT AND VALUE BY USES.

| KIND | Quantity (Cubic Feet) | Value | Value Per Cubic Foot | Per Cent of Total Value |
|---|---|---|---|---|
| *Rough*: | | | | |
| Building | 34,000 | $ 48,000 | $ 1.41 | 8.13 |
| Monumental | 2,100 | 4,625 | 2.20 | .80 |
| Other purposes | 38.120 | 50,315 | 1.32 | 8.51 |
| Total rough | 74,220 | $102,940 | $ 1.38 | 17.44 |
| *Dressed*: | | | | |
| Building | 6,565 | $ 12,629 | $ 1.92 | 2.13 |
| Monumental | 1,600 | 4,275 | 2.67 | 0.72 |
| Interior decorations | 250,014 | 465,491 | 1.86 | 78.81 |
| Total dressed | 258,179 | $482,395 | $ 1.87 | 81.66 |
| Other purposes | *a*1,875 | 5,250 | $ 2.80 | .90 |
| Grand total | 334,274 | $590,585 | $ 1.77 | 100. |

*a*—15,000 square feet in slabs 7-8 inch thick.

a. The government report on the Mineral Resources of the United States for 1908, gives $790,233 as the production of Tennessee quarries for that year.

As shown by the above report, 78.81 per cent of the total product was used for interior decoration, which is the largest proportion furnished for that purpose of any State in the Union, except California, which furnished 83.3 per cent. It is to be noted, however, that the total production of California was only $60,408 in 1908. In the total value of marble furnished for interior decorations, Tennessee ranks second, Vermont being first. The amount used in the rough for building purposes in 1909 was 8.13 per cent as compared with 32.9 per cent in 1908.

The value of marble product in Tennessee from 1898 to 1909 inclusive is as follows:

VALUE OF MARBLE PRODUCT, 1898 TO 1909, INCLUSIVE.

| Year | Value | Year | Value | Year | Value |
|---|---|---|---|---|---|
| 1898 | $216,814 | 1902 | $518,256 | 1906 | $576,259 |
| 1899 | 334,705 | 1903 | 438,450 | 1907 | 699,041 |
| 1900 | 424,054 | 1904 | 523,872 | 1908 | 761,222 |
| 1901 | 494,637 | 1905 | 536,729 | 1909 | 590,585 |

In the total value of its marble product Tennessee ranks third among the States according to the report of the United States Geological Survey on the Mineral Resources of the United States for 1908. The following table from that report gives the value of marble production by States.

VALUE OF THE MARBLE PRODUCT IN THE UNITED STATES IN 1908, AND USES.

| STATE OR TERRITORY | ROUGH | | | DRESSED | | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| | Building | Monumental | Other Purposes | Building | Monumental | Ornamental | Interior Decorations | Other Purposes | |
| Alabama | $ 898 | $ | $ 2,500 | $ 113 | $ 4,650 | $ | $ 77,000 | $ 33,419 | $ *a*118580 |
| Alaska | 38,500 | 1,688 | | 45,000 | 7,200 | 500 | 10,600 | 400 | *b*103,888 |
| California | 8,100 | 1,250 | | | | | 50,782 | 276 | 60,408 |
| Colorado | | | | | | | | | *c* |
| Georgia | 368,981 | 342,000 | 78,800 | 100,000 | 17,500 | | | 9,000 | 916,281 |
| Kentucky | | | | | | | | | *d* |
| Maryland | 1,050 | 8,425 | 4,652 | 65,190 | | | | | *e*79,317 |
| Massachusetts | 1,888 | | | 110,856 | 19,786 | | 34,660 | 8,458 | 175,648 |
| Missouri | | | | | | | | | *d* |
| New Mexico | | | | | | | | | *c* |
| New York | 74,538 | 56,200 | 30,421 | 472,407 | 53,292 | | 20,000 | | 706,858 |
| North Carolina | | | | | | | | | *f* |
| Pennsylvania | 13,444 | | | 54,803 | 9,000 | 7,000 | 15,000 | 3,500 | 102,747 |
| Tennessee | 83,764 | 10,755 | 37,575 | 78,440 | 17,590 | | 551,449 | 10,660 | 790,233 |
| Utah | | | | | | | | | *c* |
| Vermont | 156,325 | 134,036 | 190 | 1,402,629 | 1,714,408 | 18,006 | 1,184,259 | 70,107 | 4,679,960 |
| Total | $747,488 | $554,354 | $154,138 | $2,329,438 | $1,843,426 | $25,506 | $1,943,750 | $135,820 | $7,733,920 |

*a* Includes Kentucky and Missouri. *b* Includes Colorado, New Mexico and Utah. *c* Included in Alaska. *d* Included in Alabama. *e* Includes North Carolina. *f* Included in Maryland.

BULLETIN 2-E

2-E

STATE OF TENNESSEE
STATE GEOLOGICAL SURVEY
GEORGE H. ASHLEY,
*State Geologist*

U. S. DEPT. OF THE INTERIOR
U. S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH,
*Director*

# PRELIMINARY REPORT

UPON THE

# OIL AND GAS DEVELOPMENTS IN TENNESSEE

By M. J. MUNN,
*Assistant Geologist, U. S. Geological Survey*

EXTRACT (E) FROM BULLETIN NO. 2, "PRELIMINARY PAPERS ON THE MINERAL RESOURCES IN TENNESSEE."

NASHVILLE
FOSTER & PARKES COMPANY
1911

# CONTENTS

# Oil and Gas Developments in Tennessee.

By M. J. Munn.

## INTRODUCTION.

This paper was written as a chapter for a reconnoissance report on the oil and gas resources of Tennessee, which is being prepared by the Geological Survey of Tennessee in cooperation with the United States Geological Survey. The data herein contained are of a reconnoissance nature, being secured from published reports, by correspondence and by a very rapid personal examination of such areas in the State as could be visited by the writer in the five weeks allotted to field work. It is believed, however, that this information, incomplete as it is, taken in connection with the discussion of the stratigraphy and structure of the rocks of Middle and Western Tennessee, already published in Bulletin 2-A—an Outline Introduction to the Mineral Resources of Tennessee, by George H. Ashley, State Geologist, will be of value to those interested in this subject.

The writer wishes to express his thanks to the hundreds of citizens of the State to whom he is indebted for much of the data contained herein.

### Early Prospecting.

Drilling for oil and gas in Tennessee dates back to the close of the Civil War. Previous to that time indications of oil and gas had been found in a number of wells drilled by early settlers in southern Kentucky and northern Tennessee along Cumberland river and its tributaries in search of brine for salt making. Accounts of this work state that a number of these holes furnished considerable quantities of oil and gas with the brine. In one or two instances it has been reported that wells exhausted of brine by constant pumping began to furnish oil instead of salt water and were abandoned in disgust by their owners. One of the earliest of these oil wells is reported to have been dug or bored as early as 1820, on Wolf river, about one mile above its mouth, near the line of Clay and Pickett counties. This well is said to have

furnished sufficient oil to cover the river and, when set on fire, to produce a "terrible conflagration." Another old well dug about 1837, near the mouth of Sulphur creek on Obey river, about 4 miles below the mouth of Wolf river, is said also to have furnished a large flow of oil.

The presence of oil in numerous shallow wells dug for water in Middle Tennessee, as well as numerous oil and gas springs, led to many test wells being drilled in the years immediately following the discovery of oil in Pennsylvania in 1859. Many of these "wild cat" wells were put down by northern men who, as soldiers in the Union army, visited this part of Tennessee during the Civil War and afterwards returned to test favorable places that they had seen. Since this early period of drilling, hundreds of wells have been put down throughout Middle Tennessee. The net results of these tests have been the discovery of three or four small pools of oil which may be said to have been of commercial size, but probably none of them, for various reasons, has proven to be a profitable investment.

A general idea of the geological location of the oil and gas pools found in Tennessee to date may be had by an examination of the accompanying sketch map of Middle and Western Tennessee.

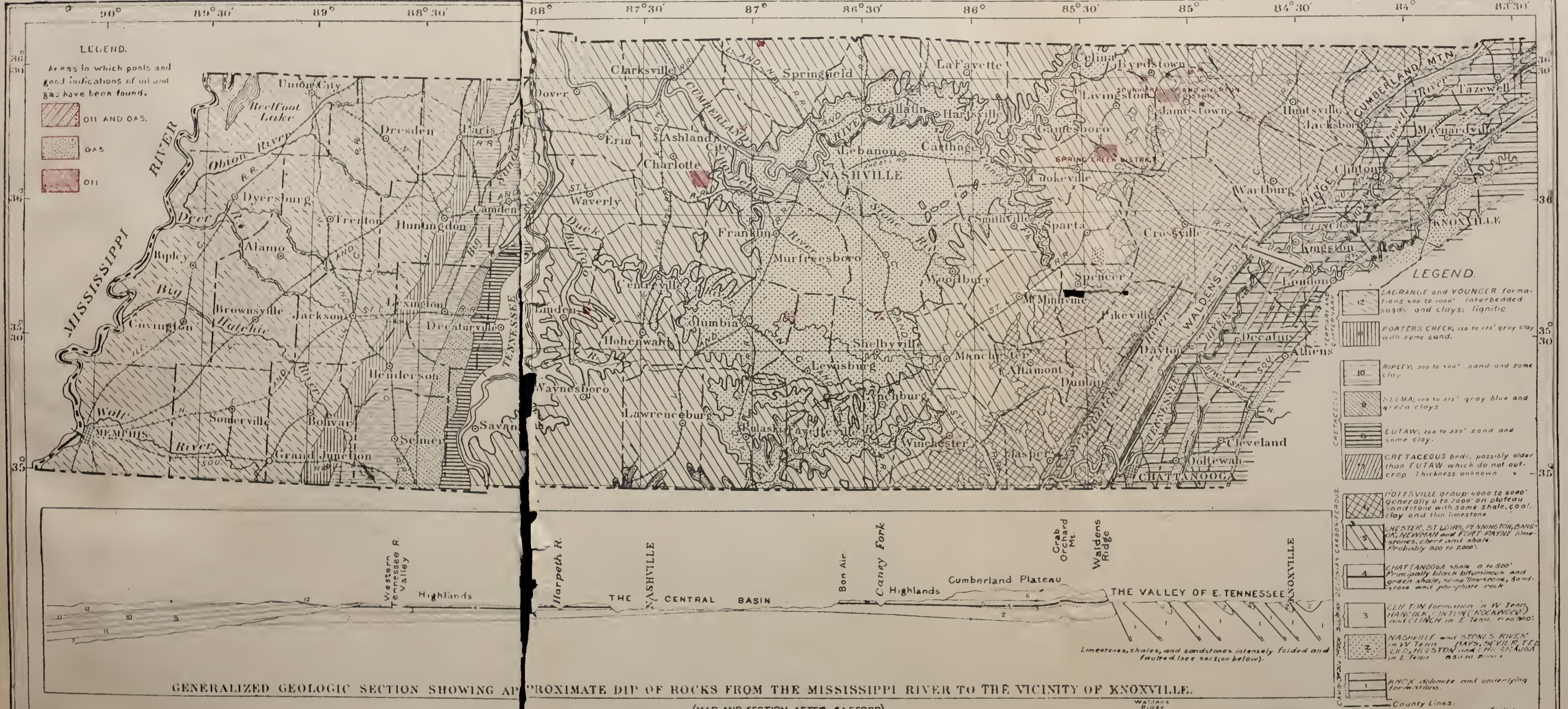
## OVERTON COUNTY.

### SPRING CREEK OIL DISTRICT.

*Early Developments.*—As already mentioned in Part A of this Bulletin, an oil pool was discovered on Spring creek, Overton County, in 1866. The first well in this pool was drilled to a depth of 126 feet near an old oil spring. The well was begun in the Fort Payne formation about 172 feet above the black Chattanooga (Devonian) shale. A small quantity of oil was encountered at a depth of 19 feet, and at 26 feet, 2,600 barrels were pumped from the well. This oil was accompanied by sulphur water. Later the well was deepened to about 52 feet, when oil was struck in such quantities that it flowed a column 30 feet above the mouth of the well. This well flowed for three months and thousands of barrels were lost for want of tankage. Twelve months later 600 barrels of oil were pumped from the well, and a year later it was again deepened to 126 feet, where gas was encountered and the well abandoned.

The next well drilled was known as the Jackson well, located on the Buck farm on Hurricane creek, about ¾ mile from the Newman well.


90°
89° 30′
89°
88° 30′
LEGEND.
Areas in which pools and good indications of oil and gas have been found.
OIL AND GAS.
GAS.
OIL
36° 30′
36°
35° 30′
35°
MISSISSIPPI RIVER
Union City
Reelfoot Lake
Obion River
Dresden
Paris
Dyersburg
Deer R.
Trenton
Huntingdon
Camden
Alamo
Ripley
Big Hatchie River
Brownsville
Jackson
Lexington
Covington
Decaturville
TENNESSEE
Henderson
Wolf River
MEMPHIS
Somerville
Bolivar
Selmer
Savan
Grand Junction
Western Tennessee R. Valley
Highlands
GENERALIZED GEOLOGIC SECTION SHOWING AP
0 12 24 36 48 Miles
SKETCH
Sho




SKETCH MAP OF MIDDLE AND WESTERN TENNESSEE
Showing General Distribution of Outcroping Geologic Formations.

*Record of the Jackson Well.*

| | Thickness Feet | Top Feet | Bottom Feet |
|---|---|---|---|
| Alluvial soil | 9 | 0 | 9 |
| Flinty limestone (Ft. Payne) | 165 | 9 | 174 |
| Black shale (Chattanooga) | 35 | 174 | 209 |
| Limestone and shale (Chickamauga limestone, including Normandy) | 293 | 209 | 502 |
| Total depth | | | 530 |

A small amount of oil was encountered in this well at about 100 feet, but it was drowned out by water and the well was abandoned upon completion.

The Douglas well, located about 60 feet from the Newman well, was drilled to a depth of 22 feet and abandoned after yielding a few barrels of oil.

The next development was on the Newman farm, by three wells, known as the Hoosier Nos. 1, 2 and 3. Hoosier No. 1 produced 30 barrels of oil a day at a depth of 52½ feet. This production was maintained for three weeks until the Newman well No. 1, mentioned above, was deepened to this level, when the Hoosier ceased to furnish oil. Later this well was deepened to 70 feet, when another oil-bearing zone was encountered in the cherty limestone, which furnished 110 barrels of oil per day, the supply lasting for about two years and three months, though the well was not pumped every day. This oil had a gravity of 42° Baume and is said to have furnished 60 per cent illuminating oil upon being refined. The oil was accompanied by very strong salt water. Later this well was drilled to 172 feet, at which depth the black Chattanooga shale was encountered. In or near the black shale sufficient gas was found to greatly retard drilling and the well was abandoned.

Hoosier No. 2 well producer 25 barrels of oil a day at 55½ feet from the surface, the supply lasting four or five years.

Hoosier well No. 3, located 350 feet from No. 2, produced 160 barrels a day until it was ruined by the breaking in of sulphur water.

Eleven wells were put down in this pool between 1866 and 1870 and, though "shows" of oil and some gas were encountered in almost every well at depths ranging from 20 to about 180 feet, no wells except those mentioned above supplied oil in commercial quantities.

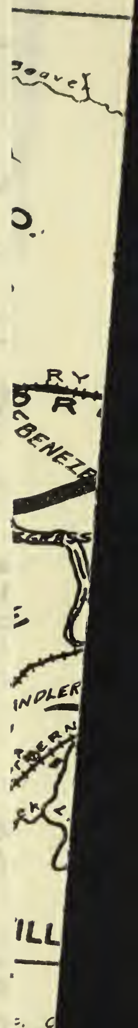
*Amount of Oil Produced.*—The total production of this field up to 1877 was probably less than 20,000 barrels. Of this amount not more than 7.000 barrels were utilized. Most of the oil was hauled in barrels by wagon to Butler's Landing on Cumberland river, a distance of 19 miles, and shipped down the river to Nashville by open boat. Some of the oil was refined at the wells and then hauled in barrels 60 miles to McMinnville, which was at that time the nearest railroad point. The cost of hauling was $3.00 per barrel to Butler's Landing and $5.00 per barrel to McMinnville. The difficulties of transportation rendered it impossible for this field to compete with the great oil fields of Pennsylvania which were being developed at that time, and after several unsuccessful attempts to operate the field at a profit it was abandoned about 1871. Since that year several attempts have been made to put the field on a paying basis and from time to time wells have been drilled by different companies. These were all failures and little or no oil has been shipped from the field since 1871.

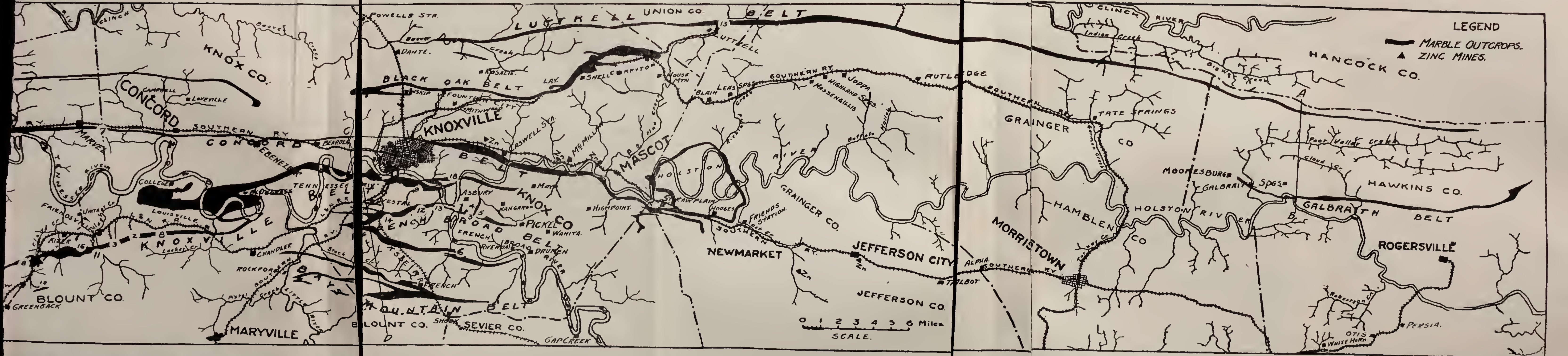
*Later Developments.*—Within the last few years the Tennessee Oil & Gas Company has acquired by lease and by purchase a large body of land in this vicinity, including the farms on which the early wells were located. This company began operations in 1909 and up to the time of the writer's visit in July, 1910, had put down three or four wells and were then running two strings of tools. The writer was informed that most of these wells contained either oil or gas, but that they are all of small daily capacity. No oil was then being pumped from the wells and it is probable that the capacity of the entire field would not exceed 10 barrels per day for the first six months, if pumped daily.

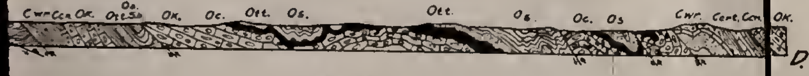
*Oil-bearing Rocks.*—The oil of the Spring creek field apparently comes entirely from crevices in the Fort Payne formation which lies above the black Chattanooga shale. Pools in it are therefore probably much more erratic in occurrence than if they were found in a regular oil sand. This may be due in part to the movement of underground water.

## SCATTERED TEST WELLS IN OVERTON COUNTY.

A well drilled in Eldridge Cove, about 3 miles northeast of the oil pool on Spring creek, is said to have been a strong gas well, but nothing is known of its capacity or lasting qualities. A well on the Gilland farm, near Oak Hill, and another on the G. T. Looper farm, at the forks of Dry Hollow, 2 miles northeast of Brushing, are both said to have furnished good "shows" of gas. Another test well put

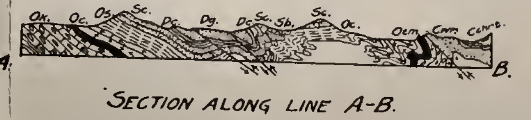




SECTION ALONG LINE C-D

SKETCH MAP SHOWING OUTCROPS OF THE HOLSTON MARBLE.
BASED ON MAPS OF U.S. GEOLOGICAL SURVEY.
SCALE 4 MILES = 1 INCH.



SECTION ALONG LINE A-B.

KEY TO MARBLE QUARRIES (CONTINUED)

10. MEADOW MARBLE CO.
11. QUAKER MARBLE CO.
12. JOHN M. ROSS.
13. THE ROSS AND REPUBLIC MARBLE CO.
14. ROYAL MARBLE CO.
15. H. B. STAMPS.
15. TENNESSEE PRODUCERS MARBLE CO.
17. UNITED STATES MARBLE CO.
18. THE VICTORIA MARBLE CO.


SPRING CREEK OIL DISTRICT OVERTON COUNTY, TENNESSEE.

down about 1¼ miles south of the Looper well was a dry hole. A well on the L. D. Buchanan farm at Livingston, drilled by the Standard Oil Company to a depth of 2,080 feet, found only small "shows" of oil and gas.

In the northern part of this county many oil and gas springs have long been known. A number of these, located on Eagle creek, led to the drilling, between 1866 and 1877, of several wells on this creek near the boundary of Overton and Pickett counties. These wells started at about the top of the Chattanooga shale, finding more or less oil at from 50 to 300 feet from the surface, most of the supply being at less than 100 feet. The total production of this district probably did not exceed 1,000 barrels, some of which is said to have been hauled to Butler's Landing for shipment down Cumberland river. The decline in the price of oil when the great Pennsylvania fields were opened made these small wells unprofitable and the field was abandoned. Subsequently little or no effort appears to have been made to discover and develop pools in this vicinity.

## PICKETT COUNTY.

### SPURRIER AND RIVERTON OIL DISTRICT.

For data relative to the oil and gas developments in the vicinity of Spurrier and Riverton the writer is largely indebted to Mr. J. H. Compton of Riverton, than whom no one was more intimately connected with the development of these fields.

The outcropping rocks of this region are all of Carboniferous age. The lowest of these is the Fort Payne formation of Mississippian age, consisting of calcareous shale, a thin sandstone, some limestone and bedded chert. This formation is exposed along the steep valley walls for about 250 to 300 feet above the principal stream. Overlying the Fort Payne formation is 400 to 500 feet of Newman limestone, near the middle of which occurs a sandstone lentil which ranges from 20 to 60 feet in thickness. This formation caps the river plateau and extends well up the sides of the higher hills. Above the Newman limestone is from 100 to 200 feet of Pennington shale, also of Mississippian age. The Pennington is overlain by from 100 to several hundred feet of sandstones, shales and conglomerate of the Pennsylvania "Coal Measures."

Underlying the Fort Payne formation and entirely below drainage occurs the Chattanooga shale (Devonian), ranging from 25 to 30 feet

in thickness. This well known geologic marker here lies unconformably upon Ordovician rocks, the Silurian limestones and shales being absent. The uppermost Ordovician rocks belong to the Chickamagua limestone. They consist of shales and limestone in which a few thin sandstones have been reported from well records.

The oil and gas appear to come entirely from the Ordovician rocks and are found at numerous horizons through more than 1,500 feet of strata, though most of the production comes from the upper 500 feet. Most of the oil is the heavy, dark green to black oil so commonly found in limestones, but in a number of wells a light amber oil of excellent quality has been found. This oil occurs in what is spoken of as "regular oil sands" at depths generally below the oil-bearing horizons in the limestone. As to the exact nature of these "sands" the writer has no personal knowledge.

From the early settlement of the country many oil and gas springs have been known to exist along the east and west forks of Obey river and their tributaries in Overton, Fentress and Pickett counties. In 1892 Mr. Bruno Gernt of Allardt and others, known together as the "Miss J. W. Stone syndicate," leased land in the vicinity of Spurrier, Pickett County, and drilled a well for oil. This well was located on the J. L. Lacey farm about one mile northwest of Spurrier, on the banks of Obey river. It started in the Fort Payne formation, and about 61 feet above the Chattanooga shale. At a depth of 286 feet this well flowed oil temporarily until the supply was shut off by fresh water. It was later drilled deeper and more oil encountered at depths of 297 and 307 feet. This well is said to have reached a depth of 1,000 feet, flowing for a short time at the rate of 800 barrels per day and later pumping at the rate of 25 barrels per hour. Great trouble was experienced, however, in preventing invasions of fresh water into the well. The following record of this well has been given:

*Record of Lacey No. 1 Well, Spurrier, Tenn.*

| | Thickness Feet | From Feet | To Feet |
|---|---|---|---|
| Shales, etc. | 64 | 0 | 64 |
| Chattanooga shale | 28 | 64 | 92 |
| Limestone and shale | 268 | 92 | 360 |
| Limestone, siliceous (brown) | 373 | 360 | 733 |
| Shale, blue, soft | 150 | 733 | 883 |
| Limestone and shale alternating | 117 | 883 | 1,000 |

Salt water was also encountered in this well at 370 and 500 feet, but it is said to have been easily exhausted by pumping.

Following this discovery of oil more than a dozen wells were drilled in Spurrier within the next few years. Lacey well No. 2 reached the Chattanooga shale at 82 feet and got "shows" of oil at depths of 211, 216, 220 and 256 feet and salt water at 360 feet. A well on the James Boles property on West Fork, a short distance from its mouth, found oil at a depth of 425 feet, which is 337 feet below the top of the black Chattanooga shale. Well No. 2 on this farm at Spurrier furnished only a "show" of oil. Another well on the C. Dilbury property near the mouth of West Fork also had a "show" of oil and gas at a depth of 425 feet. The R. Robbins well No. 1 found an amber colored oil of excellent quality at a depth of 242 feet. In the R. Reagan well No. 2 the amber oil with gas was encountered in what is said to be a "regular oil sand" 20 feet or more in thickness. Well No. 1 on the Reagan farm was a dry hole. The M. Pedgett well No. 1 found oil at 265, 294 and 354 feet. This oil was accompanied by water which quickly shut off the supply. When a 3-inch pump was put into the well and the water exhausted it is said to have flowed at the rate of 50 barrels per day, but when pumping ceased the water again shut off the supply of oil. The above mentioned wells are located to the east and south of those on the Lacey farm.

A well drilled about 1 mile west of the Lacey No. 1 on the S. Hind farm found the Chattanooga shale at a depth of 80 feet, where it was 29 feet thick. In this well a good "show" of oil was found at 180 feet. About 1¼ miles north of the Hind well on the A. Winningham farm a well was drilled which found traces of oil and considerable gas and salt water at the following depths: salt water, 210; gas and trace of oil, 328, 334, 364 and 384 feet.

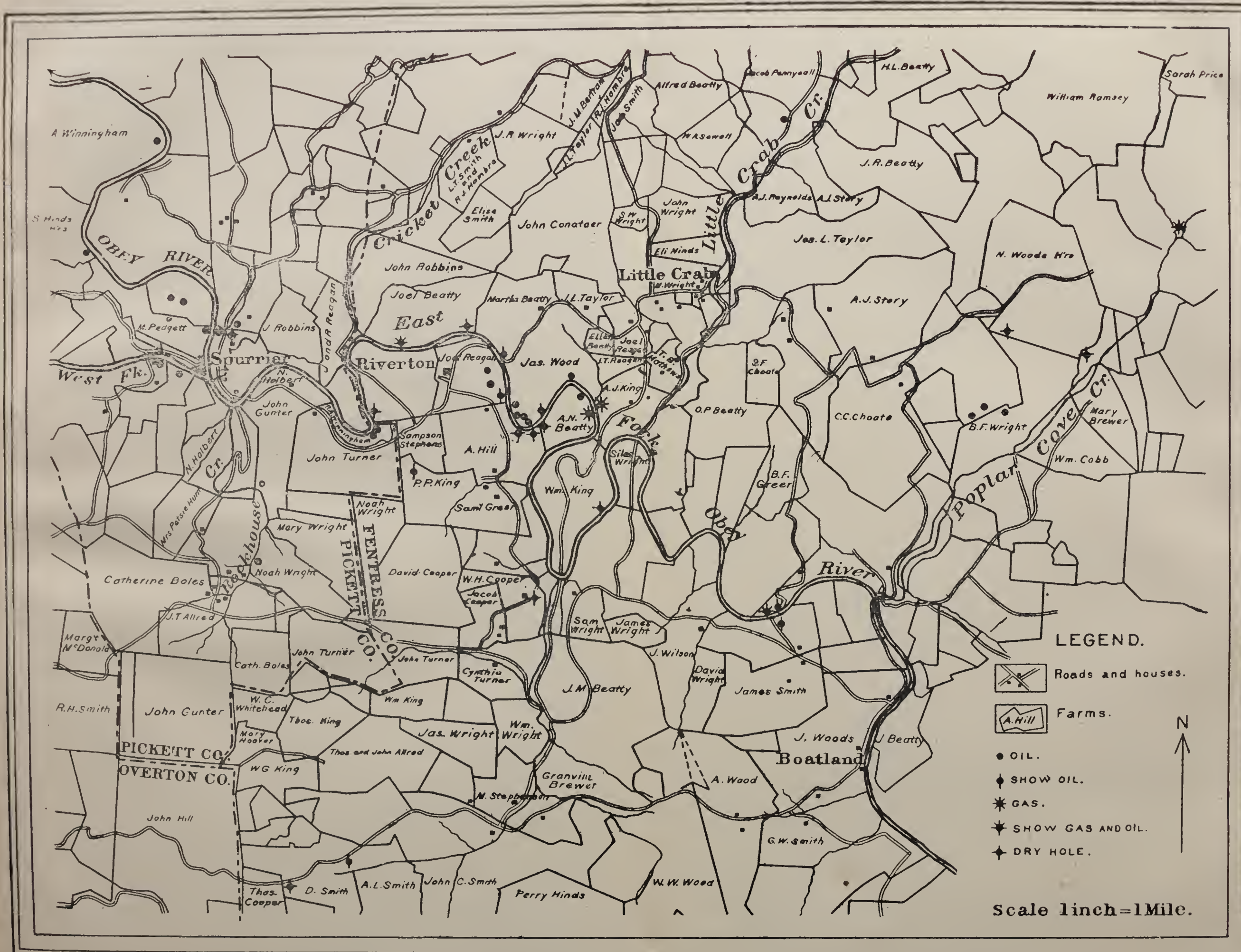
In 1896 a well was located at a shoal known as Bob's Bar, on the east fork of Obey river, 3 miles east of Spurrier in what has come to be called the Riverton field. Oil was encountered in this well at a depth of 275 feet in such quantities that it is said to have flowed for 14 hours in a solid 6-inch stream from 5 to 20 feet above the casing, after which it caught fire and burned, consuming derrick, tools, tank, etc., and continued burning until the well ceased to flow. When put to pumping this well is said, on authority of its owner, Mr. James H. Compton, of Riverton, to have produced at the rate of 600 barrels per day. The following record of the Bob's Bar well has been kindly furnished by Mr. J. H. Compton.

*Record of the Bob's Bar Well, Riverton, Tenn.*

| | Thickness Feet | From Feet | To Feet |
|---|---|---|---|
| Alluvium | 10 | 0 | 10 |
| Dark calcareous shale and shaly limestone | 70 | 10 | 80 |
| Chattanooga shale (black) | 28 | 80 | 108 |
| Limestone (varying in texture, color and hardness) to bottom of well at | | | 275 |

The oil-bearing zone in this limestone was subsequently shown to be about 100 feet thick. The well was eventually drilled to a depth of about 1,000 feet, the particulars of which are given below.

Previous to the drilling of the Bob's Bar well there were no facilities for transporting the oil from this region. The fine showing made by this well induced the Cumberland Pipe Line Company to build two 20,000-barrel steel tanks on the Lacey farm and to lay a pipe line from them to this well on the condition that it would be pumped by its owners until a full test of its capacity might be made. In 1895 and 1896, when about 18,000 barrels had been produced from it, the indications of a steady production were so good that the Cumberland Pipe Line Company laid a 4-inch pipe line to the field from its nearest branch in southern Kentucky. Supplied with a market for the oil, drilling operations were resumed and a number of wells put down in the vicinity of Bob's Bar. Of these, Wood No. 2, located about 400 feet away, reached the "pay" sand at about the depth of the Bob's Bar well. When this well "came in" the Bob's Bar ceased to furnish oil and began to furnish large quantities of fresh water. After a number of wells had been drilled in this field and great trouble experienced in preventing the wells from becoming flooded with salt water, Mr. J. H. Compton, the present owner of the field, devised a means of exhausting the supply of fresh water by raising the casing in the wells to a point just below the source of supply. When this was done over the entire field and the water in the oil horizon pumped off, the wells began producing their normal supply of oil. Woods No. 5 greatly reduced the capacity of the Bob's Bar well, but when the latter was drilled deeper it exhausted the oil from Woods No. 5. Later, when the Woods No. 5 was drilled deeper, the supply of oil again came entirely from that well. The supply of oil thus shifting from one well to the other until the entire thickness of the oil-bearing limestone (about 100 feet) was penetrated by both.




SPURRIER—RIVERTON OIL AND GAS DISTRICT, PICKETT AND FENTRESS COUNTIES, TENNESSEE

The Riverton field consists of about 17 wells, closely grouped along the river in the vicinity of Bob's Bar. Here the Joe Reagan wells, Nos. 2, 3 and 4, furnished a few barrels of amber oil from what is considered by Mr. Compton to be a sandstone ranging from 8 to 10 feet in thickness and at a depth of 625 feet. These wells are all located in the valley of east fork of Obey river west of Bob's Bar well. On the north side of the river opposite Joe Reagan's No. 2 a deep well was drilled on the Martha Beatty farm, which found a "show" of oil in a sandstone 80 feet thick at a depth of 1,700 feet. No other oil or gas horizons were reported in this well. The James Wood wells, Nos. 2, 3 and 5, produced crevice oil from the same oil horizon as the Bob's Bar and Wood No. 1. No. 4 on this farm was dry. On the bluff south of the river the A. Hill well No. 3 found 28 feet of Chattanooga shale at 305 feet and a show of green oil with gas at 638 feet. Well No. 4 on this farm found 30 feet of Chattanooga shale at 305 feet, gas at a number of places between four and five hundred feet and also at 560 feet, and a peculiar shale, known as the Pencil Cave, at 870 feet, with a little gas below, the total depth of the well being about 900 feet. East of the Bob's Bar well two wells were drilled on the A. Beatty farm. No. 2 on this farm showed oil at 270 feet and at 600 feet the heaviest flow of gas in the field was encountered. The No. 1 on this farm was a small oil well. Across the river from Beatty No. 2 the well on the A. J. King farm was drilled to a depth of 1,100 feet and is reported to have encountered gas in small quantities at no less than 22 horizons. The above named wells in the Riverton field have furnished all the oil.

The exact amount of oil produced from the Spurrier-Riverton district is not known. The total amount piped from Tennessee by the Cumberland Pipe Line Company, as stated by that company, amounted to 58,776.34 barrels. Of this, 41,462.56 barrels came from the James Woods farm at Riverton, and 50.81 barrels from the Joel Reagan farm in the same field. It is believed that a considerable portion of the remaining 17,262.97 barrels came from the Spurrier field. Of the 41,462.56 barrels produced from the James Woods farm, the Bob's Bar or James Woods No. 1 well is said to have furnished about 36,000 barrels, besides the large amount lost before the well was gotten under control.

*Test Wells in the Vicinity of Spurrier and Riverton Fields.*—Of the test wells drilled in search of other pools in this vicinity one on the W. H. Cooper farm, about 2 miles south of Riverton, found good "shows" of oil at 540 and 900 feet. About 3 miles southeast of Bob's Bar well on East Fork at a place where oil seeps from the river

bluff three wells were put down, all of which had good "shows" of oil but not in paying quantities. One of these wells, the David Beatty No. 1, furnished light amber oil similar in quality to that of the Riverton field. In another the gas pressure was sufficient, it is said, to blow the tools from the well several times during drilling.

A small oil pool was found on Poplar Cove Creek about 5 miles east of Riverton. Here the C. C. Choate well No. 1, drilled by the Obey River Oil Company, reached the Chattanooga shale at 245 feet, the shale being 30 feet thick. At a depth of 730 feet a dark, heavy oil was encountered in this well, which is said to have flowed for seven hours, after which the supply was shut off by an invasion of fresh water. By the use of large pumps this water was temporarily kept in check; during this time the well produced from 30 to 40 barrels per day of heavy black asphaltic oil. A pipe line was laid from Spurrier to this field and oil taken from it for about one year. In well No. 2 on this farm oil is said to have been found at a shallower depth than in No. 1, the maximum daily production being about 30 barrels, which lasted only for a short time.

Cobb's well No. 1 on an adjoining farm furnished a "show" of dark heavy oil, and after being abandoned for five years this well still stands full of oil. About one mile north of the Cobb's and Choates' wells test wells were put down on the farm belonging to the heirs of N. Wood and on the L. B. Chism farm. These were drilled to a depth of about 700 feet without finding either oil or gas.

Between the Spurrier and Riverton fields a number of tests were made in an endeavor to connect the two productive areas. Three of these wells were on the Joe Beatty farm. No. 1 was dry at 700 feet; No. 2 had "shows" of oil and gas at about 600 feet, probably from the so-called "amber sand;" No. 3 penetrated the Chattanooga shale at 60 to 90 feet and obtained gas at 140 and 358 feet. A test well on the R. A. Winningham farm is reported to have produced 1½ barrels of amber oil per day, the oil sand being from 340 to 351 feet in depth. Well No. 2 on this farm produced about ½ barrel of amber oil per day at 360 feet, the "sand" being about 10 feet thick. A test well on the P. P. King farm southeast of the Winningham wells found the Chattanooga shale at 305 to 335 feet and a "show" of oil at 540 feet, the total depth being about 693 feet. Two miles north of the Winningham wells a deep test well was drilled on the John Robbins farm which is said to have penetrated to the 80-foot sandstone mentioned in the Martha Beatty well. In the Robbins well this sand is said to have furnished a "show" of oil. This sandstone was also reached in a deep

test on the J. P. Reynolds farm about 3 miles northeast of Riverton at a depth of 1,781 feet, where it is said to be between 70 and 80 feet thick. In this well the Chattanooga shale was found at a depth of 243 feet and shows of oil at 210 and 310 feet.

Southwest of Riverton on Rock House creek two test wells were drilled. One of these on the John Hunter farm found the Chattanooga shale at 82 feet, gas at 144, 150, 190, 270, 336, 358 and 620 feet, with a "show" of oil at 345 feet. Sulphur water was encountered at 685 feet which rose about 1,200 feet in this well. Total depth of the well 1,689 feet. The other well on the Noah Wright farm found the Chattanooga shale at a depth of 131 feet. In it amber oil which filled the hole was found at 435 feet and is said to still drip from the well mouth. The following statement concerning the analysis of a sample of oil from this well is taken from an article by Mr. E. J. Schmitz, published in the Engineering and Mining Journal, March 7, 1896, p. 728:

"The sample of crude petroleum, Noah Wright well, Rock House Creek, Pickett County, Tenn., received January 31, contains no rhigolene or gasolene. It commences to boil at 90° C. and yielded:

| | | | |
|---|---|---|---|
| Naptha | 3.8% | Specific gravity comb. | 0.703 |
| Benzoin | 1.8% | | |
| Kerosene to 204° C. | 15.2% | Specific gravity comb. | 0.750 |
| Kerosene to 260° C. | 14.8% | Specific gravity comb. | 0.801 |
| Kerosene to 306° C. | 12.8% | Specific gravity comb. | 0.830 |
| Heavy parafine oil | .51.6% | Specific gravity comb. | 0.859 |

The latter on standing over night had already partly crystallized (parafine). The oil yields to treatment with oil of vitriol. Original specific gravity 0.625."

About six miles southeast of Riverton two wells were drilled on the Duncan Smith farm. In well No. 1 the Chattanooga shale occurred at 307 to 400 feet and amber oil was found at 819 feet. The well produced about ½ barrel per day from a 6-foot sand. Gas was also found at a number of places in this well. Well No. 2 on the Smith farm was a dry hole.

*Abandonment of the Fields.*—When the greatest trouble was being experienced in the Spurrier and Riverton fields from flooding of wells by fresh water and at a time when the production of the field was reduced to a few barrels per day, a tax was laid by Pickett County on the pipe line of this district. Up to this time the pipe line had not proven to be a paying investment, and this fact, together with the falling off in production of the district; the failure of test wells at various points to find oil in paying quantities, and the additional ex-

pense of what was thought by the Cumberland Pipe Line Company to be an unjust tax, led to the taking up of the pipe line in 1906 from Spurrier to the Sunnybrook field in southern Kentucky. Thus deprived of a market for the oil, development work in this region came to a standstill and the producing wells fell into disuse.

*Future Possibilities of this District.*—The greatest apparent drawback for oil and gas in this district is the possible lack of good reservoir rocks. From the development work already done it seems probable that as a whole this area is one in which the processes of accumulation have been at work and that a large quantity of oil is present in the rocks at comparatively shallow depths. If this is true, and if good reservoir rocks, such as creviced beds of limestone and thin local beds of porous sandstone, exist here, it seems highly probable that other pools of commercial value are present.

The most likely place at which oil and gas may have accumulated is probably dependent largely upon the general direction of movement of the underground waters. In regions of this kind the greatest number of pools are generally found at or near the axes of local anticlines at places where good reservoir rocks are present. In future development work it may therefore be found of great advantage to locate test wells only after the structure or lay of the beds has been accurately determined over a large area. This knowledge, together with the data available from the wells already drilled, should be sufficient to admit of each well being so located as to test the maximum amount of territory.

With good facilities for transportation, both of the oil and of the materials used in development work, it seems possible that many pools of oil in this district may be profitably developed. From the data now at hand it is very probable that the creviced limestone will furnish many small pools under high pressure, thereby giving large daily production and short-lived wells. The amber oil horizons may prove to be local beds of porous sandstone or zones of fine broken residual chert along lines of unconformities which may be found to be sources of oil for many wells of small daily capacity and long lives. It seems probable that if such sands were shot with light charges of nitroglycerin, say 5 to 10 quarts, their production could be materially increased, especially if the oil-bearing rock is a sandstone. The object to be attained by such shooting is not so much the fracturing of the rock as it is to increase the diameter of the well, thus furnishing greater seepage surface for the oil.

## SCATTERED TEST WELLS IN MIDDLE TENNESSEE.

### CUMBERLAND PLATEAU AND EASTERN PART OF HIGHLANDS.

*Pickett County.*—Outside of the Spurrier-Riverton district proper a number of test wells have been drilled in Pickett County, of which the writer secured no data during the brief time spent in this region.

In 1904 and 1905 several wells were drilled in Pickett County by the New Domain Oil & Gas Company under the management of Mr. John A. Patton of Monticello, Kentucky, to whom the writer is indebted for the following facts relative to them. The first well drilled by this company in Tennessee was located on the W. B. Cargile property in the north-central part of the county. Several pockets of gas were found in this well, none of which lasted more than a few days. The second well was on the Samuel Rich farm, on Wolf River, 2 miles southwest of Neal and about the same distance from the Kentucky line. This well reached a depth of 1,200 feet, pockets of gas being encountered at depths of 150, 180, 198, 615 and 985 feet, the strongest flows coming at 198 and 985 feet from the surface. The peculiar pencil-like shale known as the Pencil Cave was encountered at a depth of 791 feet. A well on the G. B. Little farm on Jolly creek found 20 feet of Chattanooga shale at 14 to 34 feet and a sand with fresh water at 200 feet. Several pockets of gas were found in the well, together with a "show" of oil at 1,370 feet, the total depth of the well being 1,508 feet. The J. P. Harrison well on Obey river, 1½ miles northwest of Hull, found 20 feet of Chattanooga shale at 20 to 40 feet and was drilled to a depth of 1,200 feet without finding either oil, gas or salt water.

A well on the J. L. Martin farm near Hull, drilled to a depth of 1,398 feet, found salt water at 200 feet and pockets of gas at 288, 348 and 404 feet, and oil and gas at 458 feet and 478 feet. At 490 and 515 feet gas was also encountered, under strong pressure. The so-called Pencil Cave was encountered at a depth of 558 feet with gas at 658 feet. Some gas was found at 865, 890, 915 and 991 feet. It is said that a fine quality of sand was found in this well at 658 feet.

In the W. T. Ramsey well the Chattanooga shale 20 feet in thickness is at a depth of 340 feet. The Pencil Cave was found at 933 feet, and 31 feet of good porous sand at 1,751 feet. The total depth of the well was 1,825 feet. No oil or salt water and only slight "shows" of gas were found.

The J. H. Pendergrass well was drilled to 1,500 feet, encountering the Sunnybrook sand, 115 feet thick, at 718 feet. Three feet of Pencil Cave was encountered at 980 feet, but no oil, gas or salt water was found.

The Martin Phillips well reached a depth of 1,502 feet, finding the Chattanooga shale at 30 to 55 feet, Pencil Cave 607 feet, and a "show" of oil at 410 feet.

Two wells were drilled on the Ansolen Phillips property in 1905-6. Well No. 1 reached a depth of 1,502 feet, and aside from "shows" of gas at 118, 137, 302 and 305 feet, a small quantity of oil was found in the close sandy limestone 15 feet thick, at a depth of 1,325 feet, and another "show" of oil in the close light-colored sandstone, 10 feet thick, at 1,385 feet. A charge of nitroglycerin, containing 40 quarts, was exploded at the horizon of the first sand at 1,325 feet and another of 44 quarts in the sand at 1,385 feet. Neither of these shots increased the flow of oil sufficiently to justify pumping. No salt water accompanied the oil. In this well the top of the Chattanooga shale is 48 feet below the surface and the Pencil Cave at 605 feet, the latter being 5 feet thick. In well No. 2 on the Phillips property a depth of 1,725 feet was reached, the drill entering the Pencil Cave at 585 feet, encountering gas at 200, 425 and 475 feet, a very slight "show" of oil at 1,390, salt water at 1,585 feet and Blue Lick water at 1,710 feet. The New Domain Oil Company also drilled a well on the A. B. Walker farm to a depth of 1,754 feet, finding a good sand near the bottom and traces of gas at different horizons.

At Travisville the writer is informed that three wells have been drilled within the last few years on the Miller and Hembree farm, from which one or more tanks of oil were pumped. A well on the William Johnson farm, about 2 miles south of Travisville, is said to have furnished a strong flow of gas. Another well on the George Sells farm about 3½ miles southwest of Travisville is said to be at this date standing full of oil. From 2 to 10 miles west of Byrdtown, a number of wells have been drilled to depths ranging from 1,200 to 1,500 feet and in most all of them more or less oil and gas have been found. It is said that a well drilled on the J. W. Babb farm on Wolf river furnished considerable quantities of gas at 800 and 1,200 feet. A well drilled just east of Byrdtown in 1896 is said to have temporarily furnished a good flow of gas at a depth of 600 feet. It is very probable that a number of other wells have been drilled in this county of which no data is at hand.

*Fentress County.*—So far as known only a few deep wells have been drilled for oil and gas in Fentress County outside of the Spurrier-Riverton district. Though most of these were put down within the last 20 years, but little information is now available regarding them.

A well drilled on the Snodgrass property on Franklin creek, about the year 1875, is said to have had sufficient gas to blow the tools from it several times during the course of drilling. A well on the Obey river between Glenobey and Boatland is said to have been dry. On Clear Fork of Cumberland river northwest of Rugby, in the extreme eastern part of the county, a well drilled by the South Penn Oil Company in 1896 is said to have found some oil in the Newman limestone, about 400 feet from its top. It seems probable that other wells were drilled in this vicinity of which the writer has no data. About 1904 a well was drilled by the Phoenix Oil Company on the Ward property about 1 mile north of Jamestown which reached a depth of about 1,200 feet without penetrating to the Chattanooga shale. A "show" of oil is said to have been gotten at a depth of 900 feet.

*Putnam County.*—Aside from a well or two drilled at the northern edge of Putnam County in the Spring creek district, only two deep holes are known to have been put down in this county for oil and gas. One of these on the Martin V. Lewis property, about 3 miles west of Cookeville, is said to have reached a depth of 1,990 feet, finding only traces of oil and gas. The other well, located on the Samuel Myers farm, about 5 miles northwest of Cookeville, is reported to have found considerable quantities of gas, but no record of the well was secured.

*Scott County.*—About the year 1825 a well was drilled for brine in Wayne County, Kentucky, on the south fork of Cumberland river, just across the State line from Scott County. This well, long known as the "Beatty oil well," was located on the Beatty property about 3 miles north of Elva, Tennessee. It reached a depth of less than 200 feet and instead of brine it furnished considerable quantities of oil from the Newman limestone. At various times since the Beatty well was drilled attempts have been made to find oil in this vicinity and at places in Scott County. In 1898 a well was drilled on the Parker-Templeton property, located on Station Camp creek southwest of Elva in the northwestern part of the county. This well is said to have furnished a large flow of salt water with some oil at a depth of about 600 feet, but no authentic information can be had regarding it. About the year 1899 a well was drilled 3 miles west of Winfield by the Hydetown Oil & Gas Company. This well is reported to have furnished oil at a shallow depth in such quantities that one of the men who

worked on the well, Mr. John Cowman, subsequently stated on oath that he believed the well could have been utilized if properly equipped for pumping. It was drilled deeper, however, encountering salt water, and in reaming out the hole to reset the casing a string of tools was lost and the well abandoned. At Winfield a well was put down in 1905 on the L. E. Bryant property to a depth of 2,210 feet which proved to be a dry hole. Mr. Bryant has kindly furnished the following record of this well:

*Record of Bryant Well, Winfield, Tenn.*

| Coal (No. 3) at 100 feet, Coal (No. 1) 6 feet, at 525 feet, "Coal Measures" | Thickness | From | To |
|---|---|---|---|
| Shale (Pennington) | 90 | 900 | 990 |
| Limestone (Newman) | 375 | 990 | 1365 |
| Sandstone (?) | 300 | 1365 | 1665 |
| Shale (Chattanooga) | 38 | 1665 | 1703 |
| Limestone and shale (Clinton) to bottom at | ... | .... | 2210 |

In 1896 a well was drilled by the Forest Oil Company on the property of the Rugby Land Company in Scott County, northwest of Rugby road. This well, started about 60 feet above the base of what is known as the Briceville shale in the Pennsylvania "Coal Measures," has an altitude of about 1,280 feet above sea level. It was drilled to a depth of 2,401 feet, the bottom probably being in Ordovician rocks. The following is a detailed record of this well:

*Record of Rugby Land Company Well No. 1, Scott County, Tenn.*

| | Thickness | From | To |
|---|---|---|---|
| Soft yellow shale and clay | 15 | ... | 15 |
| Soft black slate | 15 | 15 | 30 |
| Soft black coal | 3 | 30 | 33 |
| Soft black slate | 15 | 33 | 48 |
| Hard black slate | 12 | 48 | 60 |
| Very hard white sand | 70 | 60 | 130 |
| Soft black slate | 20 | 130 | 150 |
| Very hard gray sand, | 100 | 150 | 250 |
| Hard black slate | 50 | 250 | 300 |
| Very hard white sand | 95 | 300 | 395 |
| Soft black slate | 80 | 395 | 475 |
| Hard white sand, show of tar 512–517 | 287 | 475 | 762 |
| Hard dark lime | 18 | 762 | 780 |
| Soft gray slate | 15 | 780 | 795 |
| Soft brown red shale, cave | 51 | 795 | 846 |
| Soft gray slate and lime | 27 | 846 | 873 |
| Hard dark slate | 5 | 873 | 878 |
| Soft red shale | 28 | 878 | 906 |
| Hard dark lime | 39 | 906 | 945 |
| Soft dark slate | 25 | 945 | 970 |

| | Thickness | From | To |
|---|---|---|---|
| Hard dark lime | 13 | 970 | 983 |
| Hard gray lime | 77 | 983 | 1060 |
| Hard dark lime | 60 | 1060 | 1120 |
| Soft dark slate | 15 | 1120 | 1135 |
| Hard white sand | 13 | 1135 | 1148 |
| Hard white lime | 96 | 1148 | 1244 |
| Hard light gray lime | 37 | 1244 | 1281 |
| Hard white lime (show dark green oil, 1335, 1340) | 107 | 1281 | 1388 |
| Medium gray lime | 16 | 1388 | 1404 |
| Hard gray lime | 3 | 1404 | 1407 |
| Hard slate and lime | 7 | 1407 | 1414 |
| Hard light brown lime | 21 | 1414 | 1442 |
| Hard gray lime | 31 | 1442 | 1473 |
| Hard light brown lime | 3 | 1473 | 1476 |
| Soft dark slate and lime | 8 | 1476 | 1484 |
| Hard dark slate and lime | 6 | 1484 | 1490 |
| Hard gray sand | 13 | 1490 | 1503 |
| Hard dark slate | 37 | 1503 | 1540 |
| Soft gray slate | 18 | 1540 | 1558 |
| Hard light gray lime | 53 | 1558 | 1611 |
| Very hard gray lime and flint | 37 | 1611 | 1681 |
| Soft dark gray shale | 2 | 1681 | 1683 |
| Soft black shale (Chattanooga) | 45 | 1683 | 1728 |
| Medium blue lime | 28 | 1728 | 1756 |
| Hard gray lime | 42 | 1756 | 1798 |
| Soft blue lime | 99 | 1798 | 1897 |
| Soft light brown lime | 13 | 1897 | 1910 |
| Medium light brown slate and lime | 31 | 1910 | 1941 |
| Soft blue gray slate and lime | 59 | 1941 | 2000 |
| Medium dark gray slate and lime | 388 | 2000 | 2388 |
| Medium gray and brown slate and lime | 13 | 2388 | 2401 |

Conductor 15 feet.
151 feet of 10-inch casing.
744 7-12 feet of 8¼-inch casing.
1139 4-12 feet of 6¼-inch casing.
6¼-inch casing inserted at 1131.

It is said that a well was drilled about this time on the James Richie farm on Skull Fork, about 2½ miles northwest of Rugby Road, but the writer is not sure that this well is not the same as the Rugby Land Company No. 1 given above.

During the oil boom in this section in 1896-7 a well known as the Struve was drilled in the extreme southwestern part of Scott County, on Black Wolf creek, west of Glenmary. At that time the well was reported to be 1,500 feet deep and to contain a large supply of oil. It is said to have eventually proven to be a dry hole with only "shows" of oil and gas.

*Morgan County.*—A well was drilled in 1896 by the Forest Oil Company on the property of the Rugby Land Company in the extreme northern part of Morgan County and about 1½ miles south of Rugby. The following is a detailed record of this well:

*Record of Rugby Land Company Well No. 2, Forest Oil Company, Morgan County, Tennessee.*

| | Thickness | From | To |
|---|---|---|---|
| Soft brown surface | 13 | 0 | 13 |
| Hard white sand | 112 | 13 | 125 |
| Soft black slate | 30 | 125 | 155 |
| Soft white sand, little water | 10 | 155 | 165 |
| Medium black slate | 40 | 165 | 205 |
| Soft black slate | 65 | 205 | 270 |
| Hard white sand, 4 bailers water after each screw | 85 | 270 | 355 |
| Hard black slate | 35 | 355 | 390 |
| Hard gray sand | 40 | 390 | 430 |
| Hard white sand, 4 bailers water after each screw | 65 | 430 | 495 |
| Hard gray sand | 5 | 495 | 500 |
| Hard white sand | 25 | 500 | 525 |
| Hard gray lime | 15 | 525 | 540 |
| Soft red rock | 20 | 540 | 560 |
| Hard gray sand | 10 | 560 | 570 |
| Soft red slate | 30 | 570 | 600 |
| Hard black slate | 30 | 600 | 630 |
| Hard gray lime | 10 | 630 | 640 |
| Soft black slate | 5 | 640 | 645 |
| Very hard black lime | 10 | 645 | 655 |
| Soft red slate | 35 | 655 | 690 |
| Soft black slate | 25 | 690 | 715 |
| Hard gray slate | 35 | 715 | 750 |
| Soft black slate | 10 | 750 | 760 |
| Hard black lime | 130 | 760 | 890 |
| Hard white sand | 15 | 890 | 905 |
| Hard red sand | 10 | 905 | 915 |
| Hard white lime | 250 | 915 | 1,165 |
| Hard gray lime | 5 | 1,165 | 1,170 |
| Hard gray sand | 5 | 1,170 | 1,175 |
| Hard gray lime | 40 | 1,175 | 1,215 |
| Reddish brown sand (hard) show of green oil | 15 | 1,215 | 1,230 |
| Hard gray lime | 40 | 1,230 | 1,270 |
| Hard black lime | 15 | 1,270 | 1,285 |
| Hard gray sand and lime | 10 | 1,285 | 1,295 |
| Hard black slate | 15 | 1,295 | 1,310 |
| Hard gray slate lime | 20 | 1,310 | 1,330 |
| Hard black sand | 120 | 1,330 | 1,450 |
| Soft blue slate | 5 | 1,450 | 1,455 |
| Soft black shale (Chattanooga) | 40 | 1,455 | 1,495 |
| Medium blue slate | 5 | 1,495 | 1,500 |

| | Thickness | From | Mineral To |
|---|---|---|---|
| Medium blue slate and lime | 160 | 1,500 | 1,660 |
| Hard brown lime | 10 | 1,660 | 1,670 |
| Hard blue lime | 105 | 1,670 | 1,775 |
| Medium dark gray slate | 55 | 1,775 | 1,840 |
| Medium gray slate and lime | 485 | 1,840 | 2,325 |
| Hard gray sand | 25 | 2,325 | 2,350 |
| Hard gray lime | 443 | 2,350 | 2,793 |

Bottom of coal at 12½ feet.
132 10-12 feet 10-inch casing.
388 7-12 feet 8¼-inch casing.
879 7-12 feet 6¼-inch casing.

It will be seen from the above record that a "show" of green oil was found in a sandstone at depth of 1,215 feet. No other wells are known to have been drilled in this county.

*Cumberland County.*—A single deep well drilled in 1904 by Mr. J. M. Steele for Rackow, Zimmerlee & Co., on the Forbes property, 1 mile west of Crossville, covers the development work for oil and gas in Cumberland County. This well reached a depth of about 1,385 feet when a drilling bit and a string of fishing tools were lost in the hole, preventing further drilling. The following record of this well shows the rocks encountered:

*Record of Well on the Forbes Property, Cumberland County, Tennessee.*

| | Thickness | From | To |
|---|---|---|---|
| Sand, yellow, hard and close | 0 | 76 | 76 |
| Slate, shales, and sand, fairly soft | 76 | 139 | 215 |
| "Like Trenton, hard" | 20 | 215 | 235 |
| Gritty slate and shales, soft | 45 | 235 | 280 |
| Big conglomerate, hard | 95 | 280 | 375 |
| Fire, clay, coal, etc., soft | 5 | 375 | 380 |
| Conglomerate, very hard | 55 | 380 | 435 |
| Sandstone, hard | 175 | 435 | 610 |
| Sandstone, hard, yellow | 10 | 610 | 620 |
| Dark blue lime, open | 25 | 620 | 645 |
| Dark blue lime | 55 | 645 | 700 |
| Lime and clay, dark blue | 20 | 700 | 720 |
| Shaly lime, medium soft, dark blue | 55 | 720 | 775 |
| Lime, dark blue, close and hard | 20 | 775 | 795 |
| Lime and clay, blue, fairly soft | 15 | 795 | 810 |
| Lime and slate, blue, soft | 30 | 810 | 840 |
| Lime and shale, blue, soft | 60 | 840 | 900 |
| Gritty lime, blue, hard and close | 40 | 900 | 940 |
| Gritty lime, blue, hard and close | 25 | 940 | 965 |
| Shaly lime, blue, hard and coarse | 35 | 965 | 1,000 |
| Gritty lime, hard and coarse | 80 | 1,000 | 1,080 |
| Gritty lime, white, hard and coarse | 10 | 1,080 | 1,090 |
| Lime, blue, hard and close | 20 | 1,090 | 1,110 |

| | Thickness | From | To |
|---|---|---|---|
| Lime, white, hard | 10 | 1,110 | 1,120 |
| Lime, white, hard | 40 | 1,120 | 1,160 |
| Lime, white, hard | 20 | 1,160 | 1,180 |
| Lime and sand, white and blue, hard | 5 | 1,180 | 1,185 |
| Sand, dark, hard, close | 20 | 1,185 | 1,205 |

Water at 110 feet.
Cased with 8¼-inch casing at 645.
Show of oil at 1,090, in 15-inch sample.
Flow of gas at 1,180.
Flow of salt water about 2 bailers per hour at 1,205.

It is said that several bailers of dark green oil were taken from this well, coming from a hard, white, siliceous limestone. The flow of gas mentioned in the record was sufficient to justify its use under the bailer in drilling. This well was begun in the Walden sandstone, of the "Coal Measures," and stopped in what is probably the Fort Payne chert. The Chattanooga shale not being reached, the hole is therefore entirely in Carboniferous rocks.

*White County.*—Development work in White County consists of four wells drilled in the central part of the county. Two of these wells were put down in search of brine on Calf Killer river, 3½ miles northeast of Sparta, between 1820 and 1830. Salt water, accompanied by some oil, is said to have been found at shallow depths, the former being utilized in salt making. The oil is said to have been in such quantities as to catch fire and burn on the surface of the river. About the year 1900 a well was drilled by the Diamond Oil Company, about 5 miles southwest of Sparta on the C. T. Jaston farm, to a depth of about 700 feet. This well found a strong flow of gas which was allowed to pass from the open well for several years. It is said that when set on fire this gas furnished a flame from 10 to 12 feet high, burning constantly for long periods. The well was finally capped and the gas piped to the residence of Mr. Flint Haston, furnishing an ample supply for lighting and heating. In 1903 a well was put down on Calf Killer river on the farm of Judge W. T. Smith, about 1 mile north of Sparta. This is reported to have furnished some gas, but no authentic information regarding it is at hand. Aside from the small area covered by these wells, most of which were shallow, White County remains undeveloped.

*Sequatchie Valley.*—Numerous oil and gas springs occur along Sequatchie Valley, adjacent to the fault and sharp fold where the petroliferous beds outcrop. So far as known a single deep well drilled about one mile south of Pikeville is the only test made for oil and gas in the valley. This well was started in the Knox dolomite, which lies below any known oil or gas-bearing bed of this region, which renders the area

in which this well was drilled unfavorable for these products. No facts regarding this well are available other than that it was a failure. Many shallow wells drilled for water along the valley have supplied "shows" of oil, but the folding and faulting of the strata and the fact that beds most likely to contain oil in paying quantities outcrop on the hillsides above the valley render this area unfavorable for oil and gass pools of paying size.

*Warren County.*—Between 1868 and 1870 a well was drilled to a depth of about 1 000 feet on Barren fork of Collins river at McMinnville. This well is said to have found a supply of gas that, accidentally catching fire, burned the derrick. Many years later the McMinnville Oil & Gas Company, made up principally of local capitalists, drilled another well near the first one and at a point where gas has long been known to bubble from the river bed. The second well reached a depth of about 1,500 feet. It started in the Fort Payne chert and found 55 feet of black Chattanooga shale at 194 feet. The following partial record of this well shows the nature of the rocks encountered to a depth of 279 feet, as classified by the driller:

*Partial Record of Deep Well at McMinnville, Tenn.*

| | Thickness Feet | From Feet | To Feet |
|---|---|---|---|
| Conductor | 11 | .. | 11 |
| Shale, yellow | 4 | 11 | 15 |
| Flint | 20 | 15 | 35 |
| Lime | 1 | 35 | 36 |
| Flint | 2 | 36 | 38 |
| White lime | 13 | 38 | 51 |
| Flint | 10 | 51 | 61 |
| White lime | 10 | 61 | 71 |
| Blue lime | 4 | 71 | 75 |
| White lime | 15 | 75 | 90 |
| Flint | 10 | 90 | 100 |
| Flint and lime | 30 | 100 | 130 |
| White lime | 35 | 130 | 165 |
| Flint and lime | 29 | 165 | 194 |
| Black shale (Chattanooga) | 55 | 194 | 249 |
| Black shale and lime | 30 | 249 | 279 |

This well was a dry hole.

About 6 miles southeast of McMinnville and about 1 mile north of Island Ford on the Collins river, a well drilled for water is reported to have found a "show" of gas at a depth of 75 feet. Another well, drilled in the southwestern part of the county near Hallan, in 1902 or 1903, on the farm of Chas. Higgins, reached a depth of between 1,000

and 1,200 feet, finding a good "show" of gas, but not in quantities sufficient to justify equipment for use. A dry hole is said to have been drilled on Hickory creek near the boundary between Warren and Grundy counties, but nothing is known regarding it.

*Coffee County*.—In 1871 or 1872 Mr. W. S. Higgins had a well drilled on his farm in the central part of Coffee County near Manchester. This well was drilled by water power and is said to have reached a depth of 1,312 feet. Gas in considerable quantities is reported to have been struck at a depth of 500 or 600 feet, but it was allowed to blow off from the open well until exhausted. Another well in this vicinity was drilled in 1875 or 1876 on the B. P. Beshaw property to a depth of about 1,200 feet, getting a "show" of gas. A dug well on the farm of Mr. W. P. Hickerson, about 2½ miles from Manchester, furnished a "show" of oil at about 100 feet. The last test well drilled for oil or gas in this county was put down about the year 1897 on the T. S. Colley property, 1 mile northwest of Tullahoma. This well is reported to have reached a depth of about 1,600 feet. In it 10 or 12 feet of black Chattanooga shale was encountered at a depth of less than 200 feet. No oil or gas in paying quantities and no salt water was found. At Tullahoma wells drilled for water for the city find the Chattanooga shale at a depth of about 180 feet and a good supply of excellent water directly below this shale.

## SOUTHERN PART OF HIGHLANDS.

*Franklin County*.—The following statements relative to attempts to find oil and gas in Franklin County has been kindly furnished the writer by Mr. J. L. Girton of Winchester, Tennessee, who has been closely identified with all operations in this county:

"During the year 1889 Standard Oil Company leased several thousand acres of land from Winchester west to Moore County and made survey of county and made map of county, paid royalty on leases for several years and then dropped them.

"In the first half of the year 1901, the writer leased 20,000 acres land for oil and gas and organized a company and incorporated the same for the development of the land. Drilled four holes when, by the death of the president, the company went to pieces and all work stopped.

"Well No. 1 was drilled in at a point one and one-half miles west of Winchester and was drilled to a depth of 1,580 feet. The formation was blue lime rock, thin black shale, more very hard lime rock with flint and quartz; at a point 96 feet below the surface we struck a considerable flow of gas, much more than we needed for fuel for the furnace. At another point lower

down we entered another crevice which was filled with gas and at 250 feet below the surface struck a very strong deposit of gas computed to furnish 100,000 cubic feet per day. Below this we opened several cavities of crude oil, each of which contained from a few gallons to a barrel or more and this condition continued down to about 1,000 feet, when we struck the Knox dolomite; from that point there was hardly any change to 1,500 feet, when we struck about 2 feet of green pencil slate which made us much trouble by running into the well. At 1,580 feet we struck an ocean of salt and sulphur water, which raised 1,300 feet in the hole in a very few minutes and at this point the hole was abandoned. The volume of gas was nearly as strong in the well as when it was first struck and shows considerable strength yet.

"Well No. 2 was drilled in at a point about 1,000 feet southeast of well No. 1; the rock formation about the same as in No. 1. At a depth of between 800 and 900 feet we struck a very large cavity of crude oil containing many barrels of oil. We found no gas of any amount in this hole and at 1,250 feet the drilling was discontinued.

"Well No. 3 was drilled in at a point alongside the railroad track between Winchester and Decherd. Rock formations about the same as that in wells 1 and 2. At 250 feet a strong vein of gas was struck, and lower down several inferior veins were found. When all brought together gave a rock pressure of 44 pounds to the inch. This well has been utilized for light, fuel and power for about eight years and the pressure has constantly increased all the time.

"Well No. 5 was drilled in at Belvidere, six miles west of Winchester, some five years ago. The well was drilled by the Belvidere Milling Company for either water or gas, but at 157 feet a small vein of lubricating oil was found which would afford two or three barrels per day. The drilling was continued to a depth of 260 feet and stopped. I have tested the well many times and find that the oil stands practically 30 inches deep on the water all the time. I have drawn several gallons of it from the well and used it on heavy machinery and find it a fine quality of lubricating oil. At Belvidere marsh gas is found in considerable quantities above this oil. Near Winchester in burning this gas a considerable quantity of lampblack is formed.

"Two years ago the ice company had a well drilled for water at the ice plant and at a depth of 100 feet so much gas was found that the well had to be abandoned. The machine was moved a few feet away and a second well drilled in and practically the same depth the result was the same.

"There is one seam of a porous gray lime rock along the bank of the Boiling Fork Creek that contains cavities which are full of oil and this condition exists wherever the same seam or ledge of rock can be found for twelve or fifteen miles along the banks of the Elk River. . . . . . . ."

The first two wells named above were drilled on the Doolin and Moss farms, respectively. The third was on the J. A. Hale property, and it is believed that the fourth well described by Mr. Girton was located on the Moss farm near well No. 1. These five wells are believed to cover all developments for oil and gas in Franklin County.

*Lincoln County.*—While Lincoln County is embraced by the Highlands, much of its surface consists of large valleys and lowlands where the outcropping rocks are of the same age as those of the Central Basin.

Five wells have been put down in this county in search of oil and gas or for large supplies of water. One of these was located near an old oil spring south of Argyle in the southwestern part of the county. Another well was drilled still farther to the southwest near Blanche. Both of these wells are reported to have found a small amount of oil, but details regarding them could not be secured. In the northwestern part of the county near Petersburg a well was started in search of oil on the Brown property in 1900 or 1901, but, after getting a "show" of oil, a string of tools was lost in the well at a depth of about 1,000 feet, and the hole abandoned. A considerable flow of gas with salt water was found at about 800 feet in a well drilled at Fayetteville to supply water for the city. This gas was not utilized, though it is said to have occurred in sufficient quantities to have been of commercial value if the well had been properly handled. A well drilled for water on the farm of Mr. Richard Smith at Smithland found sufficient gas at a shallow depth to be utilized by him for household purposes. Aside from the above wells a large number of shallow ones, drilled for water over the county, have shown more or less oil, gas, and some salt water, but to date wells are too few to furnish reliable data regarding the possibility of oil and gas pools of commercial size being found in this region.

*Giles County.*—A deep well drilled in search of water in Pulaski is said to have reached a depth of 2,200 feet, in which small "shows" of both oil and gas were found. No other deep wells are known to have been drilled in this county, though numerous surface indications of both oil and gas occur.

*Lawrence County.*—Three wells have been drilled for oil and gas in Lawrence County. One of these was located several miles east of Lawrenceburg, on the J. H. Stribbling property. It was drilled to a depth of about 800 or 900 feet without finding oil or gas of value. A second well drilled at Loretta to about the same depth met with similar results. The third well was put down at Iron City in the extreme southwestern part of the county. The following data concerning this well has been kindly furnished by Mr. H. P. Searcy, who was secretary of the company which drilled it. This well reached a depth of 315 feet. In the Chattanooga shale, at a depth of 200 feet, it encountered a strong flow of sulphur water which rose to within 18 feet of the surface. Below this shale "Trenton rock" was struck and penetrated to

a depth of 115 feet, where gas was encountered in such quantities as to blow the tools from the well and to partially wreck the derrick. After flowing wild for several days, the well was capped. When a short pipe was attached and the gas ignited, it "lighted up the country for miles around." After burning for two or three months the well was plugged, the 200 feet of casing drawn and the sulphur water utilized.

## THE CENTRAL BASIN.

*Marshall County.*—All but the southern portion of Marshall County lies within the Central Basin. In this county a few miles northwest of Lewisburg a well was drilled on the G. O. McRody farm for oil, about the year 1900. This is said to have reached a depth of 982 feet and to have furnished some gas. Near Ostella, in the southern part of the county, a water well drilled about 25 years ago on the John Bradford farm furnished considerable gas. South of Lewisburg in the vicinity of Yell and Cornersville many wells drilled for fresh water have supplied small quantities of oil, gas, salt water and sulphur water. One of these wells on the F. M. Parks farm is said to have furnished suffiicent gas at a depth of 170 to 190 feet to burn in a flame from 10 to 20 feet high from the mouth of the well.

*Maury County.*—No deep wells have been drilled for oil and gas in this county. A shallow well sunk for water near Lovettsville in the eastern part of the county on the W. A. Jackson farm found gas at 90 feet in such quantities as to burn for several years from 20 to 25 feet above the well mouth. Other shallow wells at several places in this county have furnished small quantities of oil, gas and salt water. There are also many oil and gas springs, one of which is located under the river bluff at Columbia, where a constant, though small, supply of oil seeps from the Lebanon limestone.

*Bedford County.*—The first well drilled for the purpose of testing for oil and gas in this county was put down in 1886 or 1887 at Shelbyville, the county seat. It was drilled by a local company on a lot owned by Mr. B. R. Whitthorne and reached a total depth of 1,000 feet. The hole was 8 inches in diameter down to 363 feet, the remainder being 5 inches. Fresh water was encountered at several places in the 8-inch hole and brackish and mineral water at greater depths. Few indications of oil and gas were encountered, and the hole was plugged at 363 feet. In 1908 this well was cleaned out, pumping machinery installed, and the water from the 8-inch hole has since been utilized by the railroad company and for ice making. In 1902 or 1903 a well was

drilled on the Swiver property, about 2 miles north of Wartrace, on the dirt road to Bellbuckle. This well is reported to have been drilled to a depth of 1,800 to 2,000 feet, but no data relative to it could be obtained. In 1904 or 1905 a well was also drilled for oil on the Matthew Skeen farm, about 1 mile north of Bellbuckle. This well is said to have been put down to a depth of 1,500 feet, but nothing is known of the results obtained. In 1906 or 1907 a well was drilled on the Zach Crouch farm, about 3 miles east of Bellbuckle, by the Wimber Oil Development Company. This well is said to have furnished no oil or gas. Many surface indications of oil and gas occur throughout this county. These consist of small seepages of oil from the limestone at many places and of local deposits of gas or small quantity encountered in shallow wells drilled for water. Several such indications have been found near Shelbyville and a noted oil seepage exists in the bluff of Duck river, south of this town. These indications led to the drilling of the deep well at Shelbyville. Considerable land is now under lease in this county for oil and gas.

*Rutherford County.*—As many as five wells have been drilled in this county in search of oil and gas but without finding either in commercial quantities. Several shallow wells drilled for water in the vicinity of Murfreesboro at various times since the Civil War furnished good indications of gas. One of these wells, on the Overall property, about 1 mile west of town, contained sufficient gas to cause the owner to attempt to utilize it for heating and lighting his residence. The gas, however, was repeatedly shut off by invasions of fresh water, and the attempt was, for this reason, a failure. These indications led to the drilling of three wells near Murfreesboro. The first of these was on the House property, about 3 miles northwest of the town; the second on the E. W. Talley farm, about 7 miles from Murfreesboro and about 2 or 3 miles southward from Florence; the third well about 3 miles southwest of Murfreesboro on the W. B. Cooper farm. This well is said to have reached a depth of more than 1,000 feet, much trouble being experienced in getting the hole down. It is said to have flowed water from near the bottom. None of the wells is said to have furnished more than good shows of oil and gas. Two deep wells have also been drilled in the extreme southern part of the county near Fosterville on the J. G. Miller and B. F. Ransom farms. In the last named well the indications for oil are said to have been very favorable, but no information regarding depth to, and amount of, oil obtained is available. Several areas of considerable extent in this county are now under lease, but no drilling operations are being conducted at present.

*Wilson County.*—Although several large blocks of leases have been taken by oil and gas companies in this county since 1896, the drilling has been confined to a single well put down by the Union Oil & Development Company of Baltimore, Maryland, on the Chambers property near Moxie, about 5 miles north of Lebanon. This well is said to have reached a depth of about 1,000 feet without finding oil or gas.

*Cannon County.*—In this county near Woodbury a well was drilled several years ago by the South Penn Oil Company on the McFerrin property. It reached a depth of about 1,700 feet without finding oil or gas. Large quantities of Blue Lick water are said to have been found between 1,000 and 1,700 feet from the surface. Another well on the Samuel Banks farm was drilled to a depth of 600 to 800 feet in search of water. It is said to have furnished gas of sufficient pressure to blow the heavy drilling tools from the well. No other deep holes are known to have been drilled in this county.

*Smith County.*—This county lies in the northeastern part of the Central Basin, and so far as known but two wells have been drilled for oil within its borders. The first well was drilled shortly after the Civil War on the McMurray property, in the extreme northwestern portion of the county near Dixon Springs. This well is said to have reached a depth of several hundred feet and to have furnished "shows" of oil. In 1896 a well was drilled by the South Penn Oil Company on the T. J. Fisher farm, a short distance northwest of Carthage, the county seat. This well reached a depth of 900 feet, finding water at 235, 255 and 400 feet from the surface. An imperfect record of this well gives a thickness of 888 feet of limestone, no mention being made of shows of oil or gas. Numerous oil and gas springs occur in this region, especially in the vicinity of New Middleton, in the southwestern portion of the county, where it is said that many shallow wells drilled for water contain small quantities of oil and gas and much salt water.

*Davidson County.*—The writer was unable to secure any definite information relative to deep wells drilled in this county, though it is very probable that several tests have been put down for oil and gas. Shows of oil and gas in wells drilled for water have been found at many places in the limestones of the Central Basin and a number occur in Davidson County, but no pools of commercial size have yet been found.

## NORTHERN PART OF HIGHLAND PLATEAU.

Comparatively little testing has been done for oil and gas in the Highland Plateau north of Cumberland river, and no oil and gas

pools of commercial size have been found there. Most of the test wells in this region were put down along Cumberland Valley in Jackson and Clay counties.

*Jackson County.*—For much of the following statement of oil and gas developments in Jackson County the writer is indebted to Messrs. S. B. Fowler and A. J. Williams, of Gainesboro, the county seat.

During the Civil War a well was drilled for brine near Cumberland river about 12 miles from Gainesboro. A good supply of salt water was found at about 180 feet, from which a large amount of salt was made. Because of the great demand for salt this well was pumped night and day for some time, resulting in the exhaustion of the supply of salt water, which was replaced by oil in considerable quantities.

A few years ago, the Gainesboro Oil and Gas Company, composed of several prominent men of Gainesboro, drilled a well 800 feet deep on the Williams farm, which flowed salt water with gas for a few days. This company drilled another well on the Fowler farm to a depth of 875 feet, finding a considerable quantity of gas at 270 and salt water with good indications of oil at 840 feet. Because of lack of funds the company suspended operations without finishing the well. Many shallow wells drilled for water in this county have found salt water and small quantities of oil and gas, but at no place have the last two been found in paying quantities. The outcrop of the Chattanooga shale and some of the underlying limestones in this county furnish numerous oil and gas springs.

*Clay County.*—Shortly after the Civil War a well was drilled at Butler's Landing on Cumberland river in the southern part of Clay County, which is said to have flowed oil in commercial quantities for a short time. Prior to 1874 a shallow well on Mill creek is said to have furnished considerable oil. Following the development of the oil field on the Cumberland river at Burkesville in Kentucky, a number of shallow test wells are said to have been drilled in Clay County, and it is reported that some of these wells furnished more or less oil for shipment, but no authentic data relative to them are at hand. No late tests are known to have been made in this county, but it is probable that some development has been done with unfavorable results. There are numerous oil springs in this county and many water wells furnish small quantities of oil and gas.

*Macon County.*—No drilling expressly for oil and gas has been reported from this county, though it is said that surface indications of both have been found at several places. Many years ago a shallow well is reported to have been drilled for brine near the site of Adams' water mill, a few miles northwest of Lafayette, the county seat. This well is said to have encountered considerable quantities of oil at a few feet from the surface, but no authentic information regarding this is available. Within the last few years leases for oil and gas operations have been secured by operators on several large tracts of land in this county, but so far as known no development work has yet been done on them.

*Sumner County.*—Three deep wells have been drilled in Sumner County in search of oil and gas. The first was drilled on the David Barrett farm located near Rockbridge in the central part of the county, about 15 miles north of Gallatin. This well is said by some to have reached a depth of 2,200 feet, and by others to have been only 1,200 feet deep. All reports agree that sufficient gas was found to warrant its use for burning lime. A well drilled on the Turner property near Sugar Grove, in the extreme northeastern part of the county, was a dry hole. In 1902 and 1903 a well, sunk about two miles southeast of Gallatin, by local capital, reached a depth of about 1,200 feet, without finding more than slight shows of oil and gas. Just over the State line in Kentucky, opposite the northeast corner of Sumner County, a small oil pool has been developed at Petroleum, and since the same general geologic conditions seem to obtain over a large area here, it is probable that future testing will develop other pools of commercial size.

*Robertson County.*—No deep wells have been drilled in this county for oil and gas, though there are said to be many surface indications, consisting of oil and gas springs and shows of both oil and gas in shallow wells drilled for water. One of the best of these shows was in a water well in the northern part of the county a few miles west of Woodview, where at a depth of less than 100 feet several barrels of oil is said to have been found in limestone.

*Cheatham County.*—One or more wells are said to have been drilled near Kingston Springs in the southern part of this county many years ago, but without finding oil or gas in paying quantities. At Sycamore, about 7 miles north of Ashland City, a good show of gas is reported at a depth of about 60 feet in a well drilled for water.

## WESTERN PART OF HIGHLAND PLATEAU AND WESTERN TENNESSEE VALLEY.

*Houston County.*—But one well has been drilled in Houston County for oil and gas. This test, located about one mile west of Erin, was put down under the direction of V. R. Harris of that place. It reached a depth of about 2,200 feet, at which point a string of tools was lost and the hole abandoned. This well had a good show of gas at about 1,200 feet but no oil. It is said to have penetrated limestone for almost the entire distance, but unfortunately no detailed record was kept.

*Dickson County.*—The first development work in this county was begun in 1866, when a well was drilled on the G. W. Brown farm, located on Jones creek, about 7 miles east of Charlotte. This well found crevice gas in considerable quantities at a depth of 187 feet, but a drilling bit was lost from the tools, the hole abandoned, and a new well drilled within 1 foot of the old one. At a depth of 295 feet oil was struck, which flowed 13 barrels in thirty minutes. It was pumped for a short time when the supply of oil was exhausted and the well abandoned. A third well was located about 50 feet from the first two which reached a depth of 565 feet, finding oil at about 162 feet. Between 200 and 300 barrels of oil were saved from this well and shipped to Nashville by railroad, where it was refined and sold. This is said to have been a good grade of oil, having a gravity of about 42° Baume. A well was drilled in 1877 by Northern producers which is said to have furnished gas at 57 feet and oil at 445 feet.

Mr. A. J. McIntire of Burns, Tennessee, who has been connected with developments in this field since 1885, says that two wells were drilled in it in 1887 by Mr. J. E. Bracey, of New York State. The first well found gas at a depth of 580 feet with a show of oil in 4 feet of rock at 250 feet. The second well found 25 feet of oil-bearing rock at 169 feet which Mr. McIntire says would have made 25 or 30 barrels of oil per day. In 1902 producers from Kentucky drilled two wells about 2 miles west of the old developments. One of these got oil at 350 feet, the other furnished gas. In 1905 a company from Chicago drilled two wells in this field, getting oil in one well, the other being a dry hole. No data is available regarding operations in this field since that time in an effort to develop a field in this vicinity.

A total of 8 or 10 wells, several of which were drilled in 1909, have been put down, in nearly all of which some oil and gas were encountered. No oil is now being taken from the field, and it is said that the

daily production of the wells remaining would probably not exceed 5 or 10 barrels per day. The writer has not yet had an opportunity to visit this field and no facts regarding depth of wells and nature of the oil-bearing rocks are available.

*Perry County.*—The discovery of several oil and gas springs on Coon creek in the eastern part of Perry County led to the drilling of two wells on this creek, about 4 and 6 miles, respectively, from Linden, the county seat. The first well was put down on the J. N. Bastin property to a depth of about 350 feet, where a good show of oil and gas, accompanied by water, was found. The other well is located about 2 miles farther down Coon creek and about the same distance from its mouth. It was drilled to a depth of about 150 feet, where a large flow of water was encountered and the well abandoned.

*Benton County.*—The western half of Benton County lies within the region of the Mississippi embayment and geologically belongs in western Tennessee. The outcropping rocks of the eastern portion of the county are those of the Highland Plateau and the western Tennessee valley. In this part a well was drilled at Eva to a depth of about 800 feet in search of water. A large supply of fresh water was found at this depth which rose to within 30 or 40 feet of the top. This water is said to bring up small quantities of oil. Another well at Big Sandy on the Louisville & Nashville Railroad in the northern part of the county got a good flow of fresh water containing traces of oil at a depth of about 500 feet.

The above mentioned fields and wells cover the important development work in the western part of the Highland Plateau, but many shallow wells drilled for water and numerous oil, gas and tar springs furnish surface indications in Wayne, Hardin, Lewis, Hickman, Decatur, Humphreys, Stewart and Montgomery counties, but so far as known little or no deep drilling has been done in them.

## WESTERN TENNESSEE.

The geologic province of western Tennessee embraces the area of the Mississippi embayment which lies west of the Tennessee river. The outcropping rocks are cretaceous or younger in age. These consist of gravels, sand, clay, marl, mud and some thin beds of limestone, sandstone and iron ore.

No pools of oil and gas have been found in western Tennessee. Slight traces of oil and small quantities of gas are known to occur in

a few wells bored for artesian water, and small oil and gas springs are said to exist near Reelfoot and Tiptonville, in Lake County. Taken as a whole, the indications of oil and gas found to date in this region are of little or no significance, being common to almost all sedimentary rocks.

Though a large number of wells have been bored in this region for artesian water, few of these have failed to secure an abundant supply at depths of 150 to 500 feet, and the more deeply buried strata have seldom been pierced.

The deepest well in the province was bored at Memphis, in search for a deep seated supply of water for the city. This well stopped in the Selma clay at a depth of 1,147 feet. The following log of this hole, taken from U. S. Geological Survey, Water-Supply Paper No. 164, by L. C. Glenn, shows the character and thickness of the material penetrated:

*Log of Well No. 109, Memphis, Tenn.*

[Elevation, 238 feet.]

| MATERIAL PENETRATED | Thickness Feet | Depth Feet |
|---|---|---|
| Yellow clay | 27 | 27 |
| Hard brown clay | 10 | 37 |
| Slightly soft brown clay | 8.4 | 45.4 |
| Gravel and sand | 4 | 49.4 |
| Soft brown clay and sand | 14 | 63.4 |
| Slightly hard brown clay | 12.5 | 75.9 |
| Stiff blue clay | 3 | 78.9 |
| Soft blue clay | 4.4 | 83.3 |
| Stiff blue clay and sand | 2.6 | 85.9 |
| Soft brown clay and sand | 1 | 86.9 |
| Very hard brown clay | 2 | 88.9 |
| Hard reddish clay | 1.5 | 90.4 |
| Hard blue clay | 15.5 | 105.9 |
| Soft blue clay | 15.1 | 121 |
| Stiff blue clay | 1 | 122 |
| Soft brown clay | 4 | 126 |
| Slightly hard brown clay | 1.3 | 127.3 |
| Stiff brown clay | 1 | 128.3 |
| Hard brown clay | 1 | 129.3 |
| Very hard brown clay | 5.7 | 135 |
| Hard brown clay | 61 | 196 |
| Slightly hard blue clay | 18 | 214 |
| Hard blue clay | 9 | 223 |
| Sandy blue clay | 53 | 276 |
| Fine sand and clay | 27 | 303 |
| Fine sand | 35.4 | 338.4 |
| Fine sand and lumps of blue clay | 41.6 | 380 |
| Coarse sand and lumps of blue clay | 10 | 390 |
| Soft blue clay | 17 | 407 |
| Sandy blue clay | 10 | 417 |
| Fine sand and clay | 15 | 432 |
| Sandy blue clay | 13 | 445 |

*Log of Well No. 109, Memphis, Tenn.—(Continued).*

| Material Penetrated | Thickness Feet | Depth Feet |
|---|---|---|
| Find sand and clay | 7 | 452 |
| Sandy blue clay | 22 | 474 |
| Fine sand | 26 | 476.6 |
| Sandy blue clay | 6.6 | 483.2 |
| Fine sand | .8 | 484 |
| Coarse sand and clay | 6 | 490 |
| Soft blue clay | 2.3 | 492.3 |
| Clay and sand | 17.7 | 510 |
| Very fine sand | 25 | 535 |
| Very fine sand and clay | 38.2 | 573.2 |
| Very fine sand | 16.8 | 590 |
| Very coarse sand with lignite | 8 | 598 |
| Lignite, pyrite and clay | 2 | 600 |
| Very fine sand and lignite | 195 | 795 |
| Soft white clay | 17 | 812 |
| Very fine sand | 53 | 865 |
| Hard brown clay | 31 | 896 |
| Fine white sand | 30 | 926 |
| Hard brown clay | 24 | 950 |
| Fine sand | 50 | 1,000 |
| Stiff brown clay | 25.6 | 1,025.6 |
| Very hard, substantial rock | .5 | 1,026.1 |
| Very stiff blue clay | 27.9 | 1,054 |
| Very hard clay | 93.5 | 1,147.5 |

At Selmer, McNairy County, a well was bored expressly for oil by the Acacia Development Company of Buffalo, New York, in 1904. This hole reached a depth of about 800 feet without finding indications of either oil or gas. This is believed to be the only test made for oil and gas in western Tennessee.

## TENNESSEE AS A FUTURE OIL AND GAS PRODUCING STATE.

### Middle Tennessee.

From the facts already pointed out, there is very probably an enormous quantity of oil scattered through the rocks of Middle Tennessee. The testing tends to show that most of this is in pools too small to be of commercial value. The wells drilled to date are so few and so irregularly distributed over the probable oil and gas territory that they are of little value as a guide to the possibilities of the region. In comparison with the oil and gas fields of Pennsylvania, southeastern Ohio and West Virginia, the reservoir rocks of Tennessee are generally few in number and of very inferior quality. Both the limestones and sandstones of Middle Tennessee seem to be too hard and compact to offer

good repositories for oil and gas accumulation. So far as known, no pools have been found in porous limestones, the oil and gas found in these rocks coming from crevices. The oil-bearing sandstones are apparently quite rare, and are usually of very local extent and too hard and fine grained to make good reservoirs. On the whole, the lack of open, porous beds of sandstone and limestone at suitable depths over this region is the most unfavorable indication noted. Structurally, so far as known, the rocks compare favorably with those of the oil and gas fields of Pennsylvania, Ohio and West Virginia, being very similar to them.

*Best Areas for Testing.*—Until a large amount of detailed geologic work is done in Middle Tennessee, only general suggestions for testing can be made. From what is known, the most favorable place for large accumulations of oil and gas seems to be the northern half of the Cumberland plateau. The fact that there are better chances of good reservoir rocks being found here, especially those above the Chattanooga shale: and also because this broad synclinorium is traversed by several broad, low anticlines of sufficient prominence to furnish good structural conditions, favor this region. The wells drilled in this territory, at Winfield, Rugby and Jamestown, by no means condemn it, and if good reservoir rocks exist here, there is no apparent geologic reason why large pools may not be found. First tests here should be located on the axes of broad, low anticlines where the dip is not less than 150 or more than 350 feet to the mile. The wells should penetrate to about 300 feet below the Chattanooga shale.

Many small though valuable accumulations of oil and gas are probably present in creviced limestones of the Highland plateau, and in the southern part of the Cumberland plateau. This source of supply will eventually prove profitable when the greater fields of the United States are exhausted.

Taken as a whole, the Central basin will probably prove by far the poorest territory for paying oil and gas pools in Middle Tennessee.

## WESTERN TENNESSEE.

There is no way of determining the relative value of the different areas in Western Tennessee, except by the drill. From the generalized geologic section on Plate I, it will be noted that the Cretaceous rocks lie unconformably upon the eroded surface of the Paleozoic rocks which, to the east, outcrop in the Highlands and Central basin. Such an arrangement of the strata is favorable for the accumulation of oil

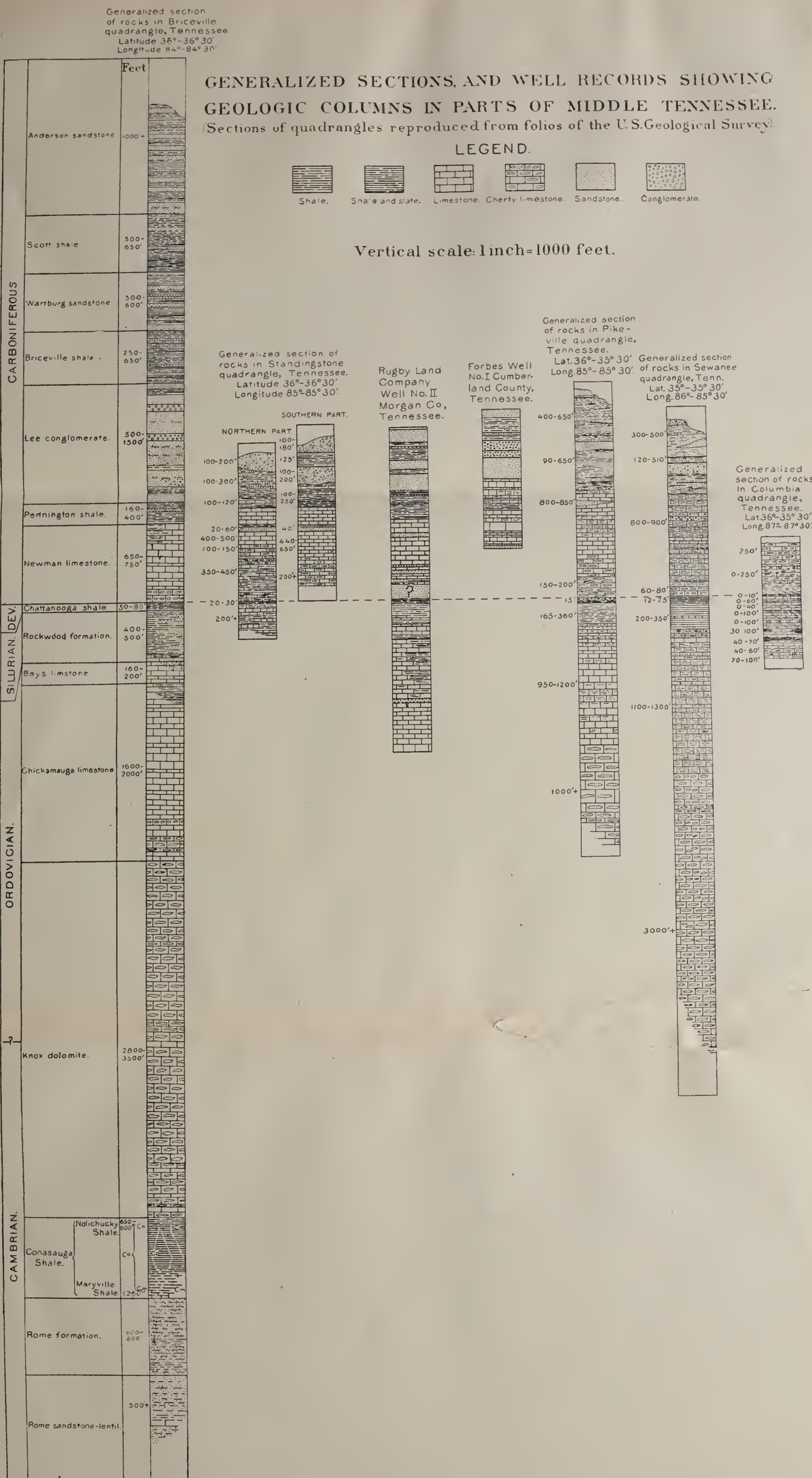
## GENERALIZED SECTIONS, AND WELL RECORDS SHOWING GEOLOGIC COLUMNS IN PARTS OF MIDDLE TENNESSEE.

(Sections of quadrangles reproduced from folios of the U.S.Geological Survey.)

LEGEND.

Shale. Shale and slate. Limestone. Cherty limestone. Sandstone. Conglomerate.

Vertical scale: 1 inch = 1000 feet.



and gas in the basal member of the Cretaceous at places where it is an open porous sand lying in contact with the Paleozoic rocks.

The Cretaceous rocks in portions of the Gulf Coastal plain in Louisiana, Texas, and Mexico have furnished large quantities of oil and gas, where they are not in contact with older oil bearing rocks, and it is possible that the Cretaceous rocks in Tennessee may be the source of oil and gas. If this is true, the open porous sands of the Ripley and Eutaw formations should furnish excellent reservoirs, and with favorable structural conditions over this region, large pools may have accumulated.

*Best Areas for Testing.*—Though no direct data are available relative to the structure of the Paleozoic rocks of this province, the surface beds are known to dip slightly and uniformly to the west. The general structure of the region, nature of the rocks, position of the unconformity between the Cretaceous and older rocks, and the water conditions in the outcropping beds tend to favor that portion of the province where the Paleozoic floor can be touched at depths of 1,500 feet or more from the surface. If any preference can be made, a belt of territory fifteen or twenty miles wide along the western side of the Illinois Central Railroad south from Jackson to the State line may be considered the best area for testing. Any wells sunk for oil or gas in this region should penetrate to the hard Paleozoic rocks regardless of water conditions in the overlying beds.

# APPENDIX A.

## RECENT DRILLING FOR OIL AND GAS AT MEMPHIS.

BY GEO. H. ASHLEY.

The preceding oil and gas report was prepared in the summer immediately following the field work by Mr. Munn. Its publication was delayed upon the completion of the maps and some modifications made afterward. Meanwhile information has come to hand of drilling being done on Hen and Chicken Island near Memphis, but reports of the wells were not obtained until this report was in page proof. Accordingly this data has been prepared as an appendix.

Three wells have been put down by the Memphis Natural Gas & Oil Company, and President Dutro, of that company, has furnished the following report of wells Nos. 1 and 3:

*Well Record No. 1, Overton Lease.*

| | Rock | Thickness | Depth |
|---|---|---|---|
| 1 | Gray sand | 35 | 35 |
| 2 | Clay | 3 | 38 |
| 3 | Gas sand | 20 | 58 |
| 4 | Blue gumbo | 4 | 62 |
| 4 | Fine gray sand | 43 | 105 |
| 5 | Fine gravel | 4 | 109 |
| 6 | Coarse gravel | 12 | 121 |
| 7 | White sand | 4 | 125 |
| 8 | Clay and lignite | 130 | 255 |
| 9 | Gray W. B. sand and lignite (10″ pipe) | 221 | 476 |
| 10 | Blue clay (chunks) | 70 | 546 |
| 11 | Gray sand and lignite | 154 | 710 |
| 12 | Gray coarse water sand (8″ pipe) | 45 | 755 |
| 13 | Gray sand and lignite (880′) | 225 | 980 |
| | Blue clay (no sample) | 155 | 1,135 |
| 14 | Brown sand (good showing of oil) | 10 | 1,145 |
| 15 | Black gas sand (gas and oil showing) | 12 | 1,157 |
| 16 | Cemented rock and gravel | 1 | 1,158 |
| 17 | Gas sand (6″) | 24 | 1,182 |
| 18 | Blue rock | 2′8″ | 1,184 |
| | Green clay | 3 | 1,187 |
| 19 | Brown clay | 7 | 1,194 |
| 20 | Lignite | 3 | 1,197 |
| | Lignite | 2 | 1,199 |

| | Rock | Thickness | Depth |
|---|---|---|---|
| 21 | Blue clay | 33 | 1,222 |
| 22 | Fine sand | 10 | 1,232 |
| 23 | Green clay | 23 | 1,255 |
| 24 | Hard clay | 45 | 1,300 |
| 25 | Fine sand | 4 | 1,304 |
| 26 | Gumbo | 20 | 1,324 |
| 27 | Fine sand | 27 | 1,351 |
| 28 | Gumbo | 8 | 1,359 |
| 29 | Artesian sand (4″ pipe) | 230 | 1,589 |
| 30 | Clay | 86 | 1,675 |
| 31 | Fine sand | 9 | 1,684 |
| 32 | Clay | 16 | 1,700 |
| 33 | Blue rock | 5 | 1,705 |
| 34 | Fine sand | 3 | 1,708 |
| 35 | Clay | 38 | 1,746 |
| 36 | Fine sand | 17 | 1,763 |
| 37 | Clay | 8 | 1,771 |
| 38 | Fine sand | 9 | 1,780 |
| 39 | Gumbo | 13 | 1,793′8″ |

Rock (supposed to be cap rock, no sample, strong oil showing).

*Record of Well No. 3, Glasscock and Bennett Lease.*

| Rock | Thickness | | Depth |
|---|---|---|---|
| Clay and sand | 22 | | 22 |
| Gumbo | 5 | | 27 |
| White sand | 3 | | 30 |
| Blue clay | 5 | Gas | 35 |
| White sand | 7 | | 42 |
| White sand | 21 | Gas | 63 |
| Blue sand and clay | 3 | | 66 |
| Blue sand and clay | 44 | | 110 |
| White sand | 19 | | 129 |
| Fine gas sand | 6 | | 135 |
| Blue clay | 27 | | 162 |
| Fine white sand | 164 | | 326 |
| Fine art sand | 100 | | 426 |
| B. C. shale | 6 | | 432 |
| Fine brown sand | 62 | | 492 |
| Blue clay | 12 | | 506 |
| Coarse art sand | 5 | | 511 |
| Bl. shale and gumbo | 71 | Containing gas | 582 |
| Fine sand | 11 | | 593 |
| Blue clay and gumbo | 97 | Gas and oil showing | 690 |
| Hard gumbo | 22 | | 712 |
| Fine brown sand | 84 | Gas and oil showing | 796 |
| Gas sand | 66 | Strong gas and oil showing | 862 |
| Clay | 18 | | 880 |

Porous oily rock. Very strong gas and oil showing penetrated this formation 13′2″.

Well No. 1 passed through 155 feet of blue clay between 980 feet and 1,135 feet. Apparently this is the Porter's Creek clay; then comes sand, clay and lignite, the sand predominating, to 1,589 feet, or for a thickness of 454 feet. As clays predominate below, and as this is about the thickness of the Ripley formation, it may be assumed to represent that formation; below would come the Selma clay, and as that formation has a thickness of 300 to 400 feet to the east, it would appear that the well stopped in that formation. The Selma clay is a light leaden gray or greenish clay when dry, and somewhat darker when wet. It will be noted that of the 204 feet of strata at the bottom of the well below 1,589 feet all but 43 feet are clay.

As many inquiries have come to this Survey in the last few months in regard to the possibility of getting oil and gas in Shelby and Tipton counties, and as the possibility of finding oil and gas in that area is doubtless largely inspired by the successful results attending drilling in Louisiana and Texas, it may be well to consider briefly the conditions found in these states, and their bearing of the problem of oil and gas in southwest Tennessee.

It may be noted that oil and gas occur in Louisiana and Texas in two very distinct ways. In the first the oil and gas has accumulated on top of a saline dome, as at Spindle Top, where large quantities of oil and gas have been highly concentrated in a very small area, usually not more than a few hundred acres, and all of the surrounding country is barren. In the other the oil and gas occur widespread in certain strata of distinct geologic age.

The work of the Louisiana State and the U. S. Geological Surveys has appeared to show that these salt domes occur along definite fault lines, or more particularly where different fault lines cross. Apparently the dome has been formed by supersaturated salt waters rising through the crevice to a certain point in the rocks where they begin to deposit the salt and the crystallizing salt exerts an uplifting force sufficient to raise the overlying strata to form the dome. In some cases the salt actually reaches the surface, in others it is buried to only a slight depth, and in still others the top of the dome may be a thousand feet or more deep, and the dome of rock salt itself a thousand or more feet in thickness. In these cases the doming of the rocks has appeared to form very favorable spots for the accumulation of the oil and gas, and when pierced by the well such domes often yield great quantities of these

substances, though usually only for a short period of time. At the surface these salt domes are usually recognized by a slight mound above the surrounding prairie or flat land. Usually the mound is not more than fifteen or twenty feet high. On the other hand, in some cases, instead of a dome or mound, a salt dome is indicated by a depression, possibly due to the dissolving of the salt, at the top, and settling of the land at that point. In addition to the topographic character most of these domes have given a distinct indication of oil and gas in what are known as gas bubbles, asphaltic "sea wax," or sour water or dirt. Commonly, too, there is an escape of sulphurous water. Where the dome of salt actually reaches the surface, it, of course, makes a salt lick, and may be recognized in that way. As before stated, these salt domes have yielded large quantities of oil and gas over a very small area; in some cases the production has reached 10,000 barrels or more a day for months; but wells sunk a short distance from the dome are unproductive. It is stated that actual experience has shown that the circle of influence of each saline uplift may be drawn with a radius scarcely over a mile in length and generally far less, and outside of that circle no oil need be looked for until the next dome is encountered.

The Caddo field, however, is an illustration of the other type of oil and gas occurrence in that region in which apparently they are not associated with salt domes. In these cases the oil and gas appear to be found in sandstones or sandy layers interbedded with impervious clay layers, and the oil and gas appear to be found almost, if not quite always, on the crest of anticlines or folds of the rocks containing the oil. The sandstones or sands yielding the oil are of Tertiary or Cretaceous age, but probably most of the oil, and gas as well, has come from the Cretaceous rocks. In a generalized section of the Caddo field it may be noted that the bulk of the gas now being obtained from that field comes from near the top of the Upper Cretaceous, while most of the oil comes from the base of the Upper Cretaceous. If the corresponding strata of Tennessee were oil or gas bearing, we should expect to find oil or gas in the Ripley formation or at the base of the Selma.

In the No. 1 well at Memphis a good showing of oil and gas is reported near the top of the Ripley, and a strong oil showing at the bottom of the well. As stated previously, well No. 1 probably did not reach the bottom of the Selma clay. It is barely possible, therefore, that had it gone further it might have found oil or gas nearer the base

of that formation, corresponding in position with the lower oil sand of the Caddo field. In the Caddo field, however, there is more than merely the occurrence of oil in sand. Leveling to the wells, and a careful study of the elevation above sea level of certain strata which could be recognized in the wells, has indicated that the rocks in that field are folded into rather distinct anticlines and synclines, and it has been found that the oil and gas occur on the anticlines. These minor folds with which the oil and gas are associated apparently cannot be recognized at the surface, but are only recognized by a detailed study of the well records. Mention is made of the fact that in that region there are numerous small mounds scattered over the ground, though whether these mounds have any connection whatever with the occurrence of the oil and gas is uncertain. These mounds have been the subject of much study by many people for several years, and no satisfactory explanation of their occurrence has yet been made.

Coming back to Tennessee, this Survey has made no detailed field examinations of the conditions in southwest Tennessee to learn if any evidences exist there of the presence of salt domes. From a general study of their distribution in Louisiana and Texas, it does not appear probable that they exist in Tennessee, and until their presence has been demonstrated they will be assumed absent.

The principal gas and oil-bearing rocks of the Caddo field appear to correspond to the upper part of the Ripley formation and the base of the Selma clay. In No. 1 well, near Memphis, a show of oil and gas is reported at what is considered to be the top of the Ripley. If the identification of the top of the Selma clay is correct, it would seem probable that that well did not reach the bottom of the Selma, though possibly coming within a few hundred feet of its base. Whether oil or gas would have been struck had the well penetrated to the base of the formation is entirely unknown.

Bearing on that point, it may be noted that in the first place the oil in the Tertiary and Cretaceous rocks occurs usually in sands or sandstones. In the second place, a study of the records of adjoining wells as well as the outcrops shows that the sandstones are lenses, often of very limited extent. This is readily seen by comparison of the records of wells Nos. 1 and 3. In the third place, experience has shown that because a sandstone lense or bed at a certain horizon carries oil or gas it is not proof that it will carry them at some other place, though the fact

that they have been found at one place gives an element of possibility to their being found at some other place at the same horizon.

This Survey has been frequently asked, what are the chances of striking oil and gas in West Tennessee? Up to the present that part of the State has not been tested with any thoroughness. A few wells have been put down, most or all of which have found shows of oil and gas. But as far as the writer has learned, not a dollar's worth of oil has actually been obtained and sold from any of them. Had one hundred wells been put down and sixty of them struck oil in paying quantities, we should reply that the chances were six out of ten; if only forty had "struck oil," we would consider the chances four out of ten; if only ten wells, we would say one chance in ten; if only one well in one hundred, we should say there were ninety-nine chances to loose to one to win. When, as in this case, not a single well has yet struck commercial oil, there is no basis for actual figures, unless the area be enlarged until it includes some area of producing wells. But in West Tennessee so few wells have, up to the present, been drilled, the fact that none of them have "struck oil" is itself of only negative value, and should not weigh against the possibility of future success.

With our present knowledge of the occurrence of oil and gas in Louisiana and Texas, it would seem: (1) that oil and gas probably exist in commercial quantities in the Tertiary and Cretaceous rocks of West Tennessee; (2) that such pools, if they exist, are probably quite small; (3) that wells striking oil there will probably be small producers, as compared with the gushers of Texas and Louisiana, but of greater length of life than those; (4) that *until* pools have actually been located and defined nine out of ten or possibly ninety-nine out of a hundred wells may be unproductive, and the cost of their sinking of no value except as showing the lack of oil and gas, though their records, if carefully kept, may have some value in interpreting the underground conditions, particularly after oil has been struck.

On the whole, therefore, it must be frankly stated that at the present time, the striking of oil in West Tennessee is a gamble in which no one should invest who cannot afford to sink nine wells or ninety-nine wells and lose without missing the money. He may not have to sink that many before he wins, or he may not win at all, even though he sink ninety-nine wells. Of course, if he does strike oil, he may be able to pay for the ninety-nine other wells and still make money. It is this

one chance that makes the game attractive to the man who can afford it.

After oil has once been struck in quantity, the problem may change, and as has been the case elsewhere, a study of the conditions under which the oil is found to occur will generally lead to other successful wells and ultimately to a full knowledge of the field.

In conclusion, the writer might add to the statement of Mr. Munn, that this bulletin is only a preliminary overlook of the field, involving no actual field surveys. But it is planned to follow it in probably one or two years by a more complete report, dealing with the oil and gas problem in this State, based not only on the data already collected, but on much additional data which it is hoped to obtain, and giving general conclusions as far as possible.

BULLETIN 2-G

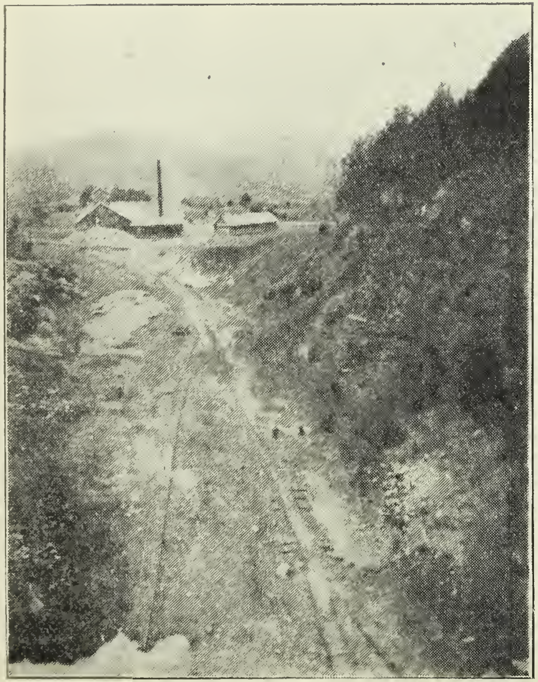


Fig. 1. Lead Mine Bend Zinc Quarry, New Prospect Mine.

Fig. 2. Lead Mine Bend Zinc Quarry, New Prospect Mine.

2—G

STATE OF TENNESSEE—STATE GEOLOGICAL SURVEY

GEORGE H. ASHLEY, State Geologist

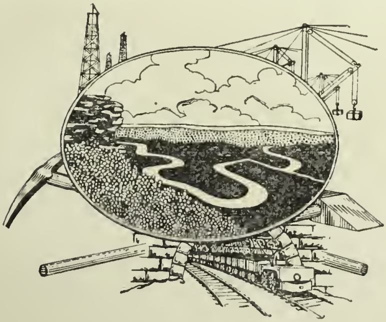
# ZINC MINING IN TENNESSEE

BY

SAMUEL W. OSGOOD

KNOXVILLE, TENN.

EXTRACT (G) FROM BULLETIN NO. 2, "PRELIMINARY PAPERS ON THE MINERAL RESOURCES OF TENNESSEE."



NASHVILLE

FOLK-KEELIN PRINTING COMPANY

1910

# CONTENTS



# ILLUSTRATIONS

# ZINC MINING IN TENNESSEE

By Samuel W. Osgood.

GENERAL DESCRIPTION OF THE DISTRICT.

The zinc district of East Tennessee was mapped in the years of 1896 to 1901, and is described in folios issued by the United States Geological Survey at that time. The position of the mines and mineral belts here described is indicated on the map accompanying the part of Bulletin 2, dealing with marble. (Bulletin 2-D.) The maps show the district in general to consist of three nearly parallel zinc belts, 40 to 50 miles long, and about 20 miles apart. These belts are each only a few hundred feet wide, and extend in a northeast-southwest direction, following the general strike of the Appalachian system of folds and faults.

The ores are contained in the Knox dolomite, a formation belonging, in part, to the Silurian and in part to the Cambrian series. In places local disturbances have given rise to cross-fissure zones of fracture. In these zones are the richest ore bodies. The ores are sulphides and they occur in the filling of the fracture zone or breccia, combined with calcite and dolomite and not in the rock. No barytes is present in these ores. Where the clay and sand of the surface is 20 to 30 feet thick, carbonates and silicates are found to overlie the sulphide ores.

The central belt occupies the valley of the Holston River, and is called the Holston Valley zinc belt. This belt has ores containing zinc with no lead and less than 0.5 per cent iron. The more northerly ore bodies, near the Powell River, and the southerly belt, near the French Broad River, carry both iron and lead.

The ore bodies along the northerly belt, which include the district in the vicinity of the Powell River, the Clinch River, and between these two rivers, near the city of New Tazewell, in Claiborne County, and in Union County, are extremely large. The ores are a compact "blende," or what is called zinc sulphide, being mined frequently in huge blocks several feet thick, assaying 45 to 50 per cent zinc. This ore, however, is extremely difficult to mill, but makes a good smelting ore.

As is shown from the photographs of the New Prospect Mine (Plate I), the open quarries, where this ore has been mined, are very extensive.

Straight Creek Mine, near Tazewell, and other mines along this same belt all have bodies of high-grade zinc "blende," which is of the same nature as the above ores, carrying a little iron in the form of pyrite, which, added to its complex milling, also makes it difficult for smelting for the purpose of making spelter or merchant zinc. However, this ore could be smeltered very successfully in a furnace for the purpose of making zinc white paint.

The southerly belt of ore, which lies near the French Broad River, and which has been opened at Leadvale, near White Pine, and Dandridge, in Jefferson County, has a complex mixture of lead and zinc, which is combined in such a fine grained intimate mixture as to make the milling of it impracticable, but which ores when found in sufficiently large bodies would make excellent ore for smelting in a zinc white paint furnace.

Both the northerly belt and the southerly belt have lead, and some iron with the zinc in the ore. It is with the central belt that this article is principally concerned, for on this belt are the most extensive operations, owing to accessibility to the railway, and to the simple nature of the ores, which are more easily treated. The Tennessee Valley ores, which occur near Knoxville, have no lead nor iron in them, and have an established reputation for being chemically pure for this reason.

The Holston Valley zinc belt is about 40 miles long, in a northeast-southwest direction, and from 50 to 700 feet wide. Knoxville is about in the center of the belt. The Southern Railway's double-track line between Bristol and Chattanooga traverses almost the entire length of the belt, hauling large amounts of Tennessee coal from near Knoxville to the coast.

### CHARACTER OF ORE.

Carbonate ores have been shipped from the district for many years. They occur in a bed of red and yellow clay overlying the dolomite containing the yellowish blende. The shipments of carbonates have been spasmodic, and the future of the district will no doubt depend largely on the success of treating the sulphide ores.

The East Tennessee zinc ores, while remarkable for their chemical purity and freedom from the undesirable iron and lead minerals usually found in zinc ores, have never until recently been of much commercial importance, owing to the low grade of the ore and the methods of milling. Actual results have shown that the cause for the lack of success was the small daily capacity of the plants, the hand-sorting of the ores bringing the cost per ton of ore treated to an abnormally high figure. The crude method of building the mills also made steady

daily operation over long periods impossible because of frequent and costly repairs.

The blende, while in large bodies of a brecciated rock, occurs in bunches or small seams as a filling in the breccia, of the fissure zone. The ore has in the past always been hand-sorted to give a mill feed assaying from 8 to 12 per cent zinc. Recently, however, it is thought to have been demonstrated by large commercial operations that the entire brecciated mass can be mined and milled on a large scale in a modern concentrating mill, maintaining a fair grade of product.

## FORMER METHODS OF WORKING.

The first mining and milling of the zinc blende ores on any considerable scale was undertaken by the Edes, Mixter and Heald Zinc Company, in 1883, at Mossy Creek, Jefferson County. This first mill was erected to wash the dumps of blende cobbed from the carbonate ores, and was so successful that in 1885 an 80-ton mill, including crusher, rolls and jigs, was erected. This mill treated hand-sorted ore from a large quarry for several years. It was closed in the panic of 1893, but was reopened by the John Weir Lead & Zinc Company in 1900, and operated for a few months. The small daily capacity and the crude equipment brought costs per ton so high that the mill was closed after a few months.

The second of these small unsuitable mills was erected by the Ingalls Zinc Company, about 1½ miles southeast of Newmarket, in 1898. The ore was quarried from near the surface. Here, again, the ore was hand-sorted, the capacity of the mill being small, like that on Mossy Creek. The ore was hand-sorted to about a 12 per cent zinc before milling, and a high-grade concentrate was shipped, but the operating costs were very high per ton of ore mined, the cause being simply the inconvenient methods for handling too small a daily tonnage.

The third of these small mills was built by the Roseberry Zinc Company, about 1½ miles west of Mascot, in 1900. This mill was an advance on former plants, but the ore was still hand-sorted in the quarry, one car of waste being secured for each car of ore. It was one of the inefficient, old-style Joplin mills of small capacity, but it shipped many carloads of high-grade zinc concentrates. The capacity was low, the mill inefficient, and poorly built for continuous operation; consequently the costs again were too high for commercial economic results. The ore was mined in a quarry at first, and later a shaft nearly 200 feet deep was sunk, and mining in stopes was begun.

The fourth of these small mills was built by the Holston Zinc Com-

pany, about ¾ mile west of Mascot, in 1903, and this was another advance, especially in the development of a more elaborate jigging system. This mill was, however, of small capacity, and the ore was still hand-sorted in the quarry. In 1905 the shaft was sunk to 150 feet, and underground stope mining was started and milling was done with no hand-sorting, which showed another advance. At this time daily capacity of the mill was small, the operation not in experienced hands, and the costs per ton relatively high.

The Holston Zinc Company's mill, shown in Plate II, Fig. 1, was partially re-equipped in 1907 along lines suggested by A. M. Hewlett, the President of the company, and operated under the writer's management. Mr. Hewlett's untimely death in 1907 had much to do with the Holston Zinc Company's failure to complete the re-equipment of the mill. However, the plant was operated in its incomplete state for several months, and shipments of concentrates were made on a scale not possible before that time in the East Tennessee zinc districts. This showed at once the correctness of Mr. Hewlett's judgment in demonstrating on a commercial scale that all it required to make a success of the Tennessee zinc ores was large capacity to reduce the "per ton" cost, a mill elaborate enough to obtain the zinc in the ore and of a sufficiently stable construction for continuous daily operation. The last year's operations on the Holston zinc belt include, besides those of the Holston Zinc Company, the shipments of carbonate ores and prospecting of its blende ore deposits by the Newmarket Zinc Company, the Grasselli Chemical Company, the Tennessee Mineral Company, and the Osgood Exploration Company.

## THE PRESENT OPERATIONS IN THE DISTRICT.

At the Holston property the ore is mined through a shaft (Plate II, Fig. 2) at a depth of 160 feet in large stopes 50 to 75 feet wide and carried to a height of 40 feet. Another level has been started above, and drifts have been started to allow of stoping at a considerable distance from the shaft. Mining is done by machine drills, operated by compressed air.

In this mine all rock is taken from the stopes for the entire width, no hand-sorting being done. All ore is dumped into the crushing plant and sent from there to the mill. The mill has three departments—a roughing department, from which a large amount of waste rock formerly picked out by hand is sent to the tailings dump, and both a fine and coarse finishing department.

The Grasselli Company, whose principal office is at Cleveland, O.,

Fig. 1. The Holston Mill at Flat Creek.

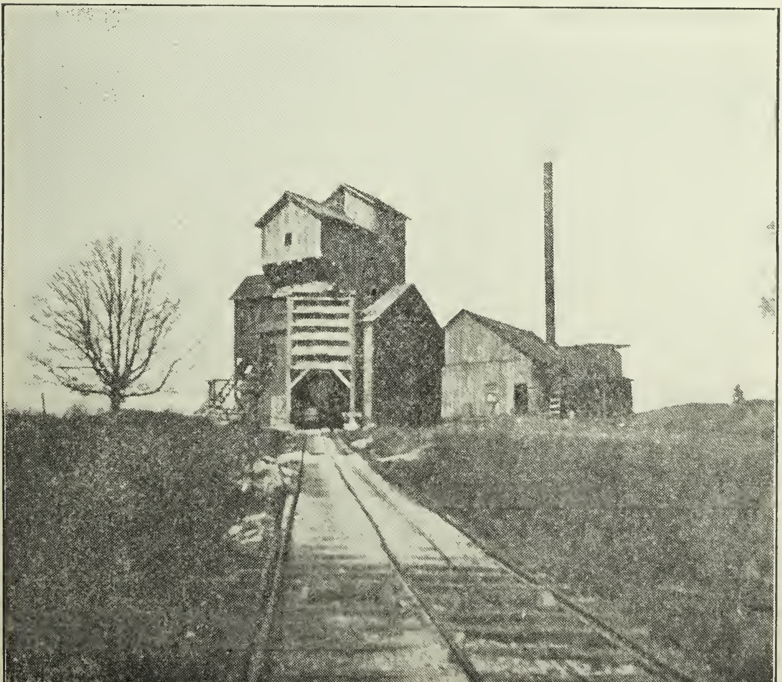


Fig. 2. The Holston Mine Shaft.

Fig. 1. The Grasselli Chemical Company's Zinc Quarry, Newmarket, Tenn.

Fig. 2. The Grasselli Chemical Company's Zinc Quarry, Showing "Carbonate" Ore Diggings.

has taken over the property of the Newmarket Zinc Company (Plate III, Fig. 1 and 2), and has shipped some 95 carloads of carbonate ores to its smelters, under the able management of Mr. W. A. Underhill. This property has now been operating over a year, and is one of the most extensive mining operations in this district. They mine their ores with the steam shovel, and are now planning an extensive enlargemet of their mill. It is gratifying to have such well known zinc operators taking a hand in Tennessee mining.

The Osgood Exploration Company, of Knoxville, Tenn., has taken over a large territory, consisting of all the mines of the old Eades, Mixter and Heald Zinc Company, and some other properties, including a lease on all the properties of the Carson-Newman College, at Jefferson City (Plate IV), and the Holston Mine, at Mascot, Tenn., and is now developing these properties. They have three large steam drill rigs at work. The holes are 6 inches in diameter, and are anywhere from 75 to 300 feet deep (or more, if necessary, to find the ore), and while from 3 to 7 holes will frequently prospect a piece of land containing 40 acres, three times this number are frequently drilled. These holes make excellent wells for watering stock when no zinc is found.

The Roseberry Zinc Company started operations in 1900. Ore was quarried, hand-picked or sorted, and sent to the crude Joplin mill. In 1904 the company made the first successful attempt to develop the Tennessee ore bodies by drilling, as had been done in Joplin. The drill disclosed a large ore body, which was opened by sinking a shaft 200 feet deep. The ore was mined in large stopes with machine drills. The ore was only roughly sorted as fed to the mill. This property adjoins that of the Osgood Exploration Company, and has recently been taken over by the Grasselli Chemical Company, who expect to erect a large mill on it.

The Tennessee Mineral Company is operating their mine and mill at Newmarket, making regular shipment of zinc blende concentrates, under the management of Mr. Kenneth R. Ayer and N. Caswell Heine, President, 1 Liberty St., New York. Mr. John Cox is the Superintendent. A quarry or open pit has been made, 165 feet long, and 40 to 50 fet wide. The ore body was found at the surface and over the ores it has been opened 50 to 60 feet deep. The ore body is nearly horizontal, and is said to be 600 feet wide. The ore is in a brecciated zone, and several seams of blende of a foot to several feet in width will average high in zinc, although no doubt the entire ore body will average much lower, probably about the same as the rest of these ores when mined on a large scale.

The old works of this property consist of an open pit or quarry,

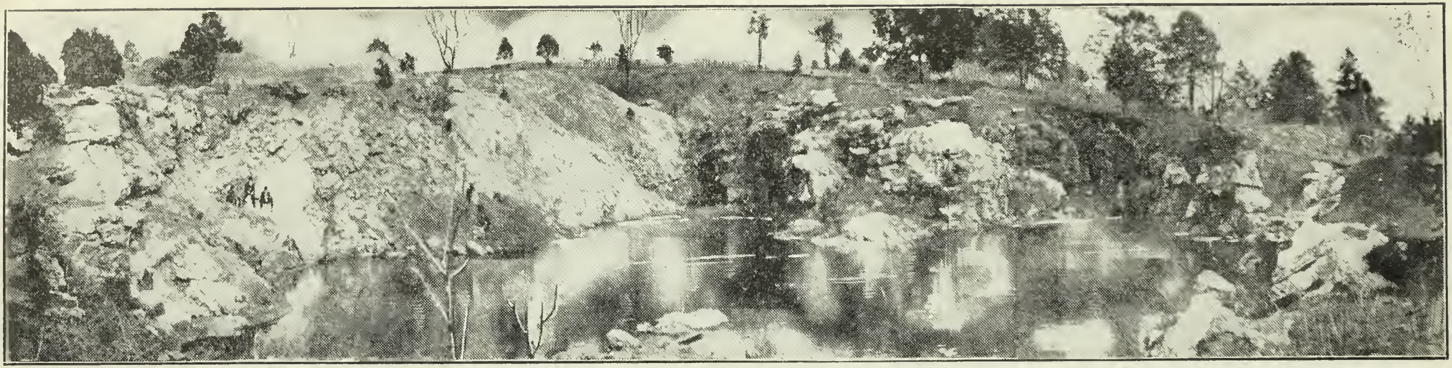


Fig. 1. Mossy Creek Zinc Quarry, at Jefferson City, Tenn., of the Eades, Mixter & Heald Zinc. Co., now controlled by the Osgood Exploration Co.

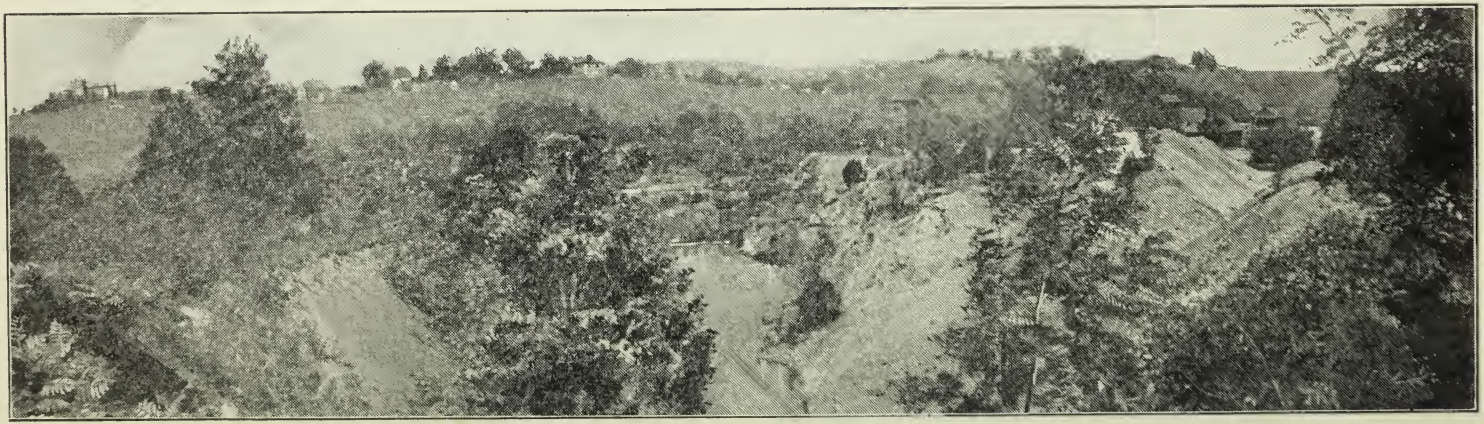


Fig. 2. The Branner Zinc Mine and Carson-Newman College Zinc Mine (looking from the Mossy Creek Mine), controlled by the Osgood Exploration Co., at Jefferson City, Tenn.

where the blende was mined for treatment in a small concentrator. The ore was mined and sorted in the quarry and hauled up an inclined track by a small hoisting engine. It was dumped upon a platform to be again hand-picked and then fed to the crusher. There were two quarries, 80 feet wide by 100 feet long, and about 5 feet deep. An old mill run shows that 500 tons of hand-sorted ore yielded 52 tons of concentrates, assaying 53 per cent zinc, which is very fair, considering the crude equipment of the mill. The new mill has been enlarged and rebuilt, and an aerial wire-rope tramway built for the efficient handling of the ores from the bottom of their large quarry to the top of the mill bins. From these the ore runs automatically by gravity through the mill, where the zinc concentrates are prepared for the smelters. On account of the extreme purity of these ores, they bring about $2.00 more than the regular Joplin prices.

The Valley Mine is the best looking of the partially opened, but inoperative mines of the belt. This mine is at Friends, on the Southern Railway, 14 miles from Knoxville. The ore body is opened by an open quarry about 50 feet long, 15 feet wide, and 10 feet deep. The quarry is near Lost Creek, and the blende appears at the surface of the ground where the creek has washed away the soil. The ore occurs in a brecciated fissure zone, and is in appearance identical with the Mascot and Newmarket ores. Carbonate ores have been shipped from the clays of the subsoil on adjoining properties, which seems to indicate a large ore body on this property.

The Loves Creek Mine, at Loves Creek, 5 miles from Knoxville, was partially explored several years ago, and good ore was found. A 50-foot drill hole showed ore all the way to the bottom. There is a good mill site with ample water for milling and good surface indications. This is at present among the inoperative properties, but the owners expect to develop it into a mine.

Throughout the entire length of the zinc range from Knoxville to Jefferson City, wherever a creek has washed its way through the soil in crossing the ore zone good blende may be seen in the bed of the creek.

## SUCCESSFUL MILLING OF TENNESSEE ZINC ORES FULLY PROVEN.

To Mr. A. M. Hewlett, the former President of the Kewanee Tube Company, now a part of the National Tube Company, belongs the credit of first solving the successful methods for the treatment commercially of the East Tennessee zinc ores. It cost the owners of the Holston Mine $150,000 to solve this problem, and finally they evolved a mill under the direction of the Knoxville firm of mining engineers,

Osgood, Carter & Company, which gave commercial recoveries that for years the lack of had prevented the operation of Tennessee zinc mines.

They demonstrated that a 1,000-ton mill of correct construction would produce at a cost of $20 per ton, 40 tons of concentrates, assaying 55 per cent zinc, worth $31 per ton gross at the works, and that such a plant, in a going condition, would cost $100,000, additional to the cost of the land. These figures are based on actual results of operation, conducted on the largest scale ever operated in this district. That this district can furnish ore in large quantities for several such mills, for years of continuous operation, is recognized by those familiar with the great magnitude of the ore bodies.

The large size of the ore bodies gives the Tennessee zinc field more of the aspect of a manufacturing proposition with its enormous supply of the raw material. Now, that it has been proven possible by modern means to successfully treat these ores, it remains merely to provide facilities, such as mills, steam shovels, crushers, etc. The range of zinc ore-bearing land comprises a strip a few hundred feet wide, nearly paralleling the main line of the Southern Railway that runs between Chattanooga and Bristol for a distance of 25 to 30 miles. This strip containing the ore bodies, varies from 6 to 50 feet wide, as is shown to be the case where it has been opened in a number of places for 20 miles in length, by a large number of drill holes, shafts with underground workings, as stopes and rooms and large open-surface quarries. These quarries are 30 to 60 feet deep, 30 to 100 feet wide, and 100 to 300 feet in length, all in ore. These ore bodies occur near the surface of the ground, and can be mined in large open quarries by steam shovels, after the manner of the Mesabi Range iron ores, with a simplicity that will make available the local supply of Southern labor, that will give extraordinary low costs of mining, comparing favorable with Mesabi Range costs. On the basis of 1,000 tons per day, it is estimated that the costs of mining and transportating to the mill will be near 20 cents per ton of ore, which will be recognized as being far below the costs possible in the Missouri or Wisconsin, or other zinc mines.

The average grade of this Tennessee zinc ore, especially that in the Holston River range, to which this refers, can be called a 60 per cent blende or "jack," or zinc ore proposition, meaning an ore which assays 4 per cent metallic zinc, and which in milling with a 60 per cent saving, will mill out as a 4 per cent ore; meaning that for every 100 tons of ore treated, a yield of 4 tons of concentrates will be obtained. These average figures of grade and milling results are based on the actual performance of practical large scale operations, and are not estimates

loosely made, but closely worked out results of such operations on a scale of 120 tons per day of this ore.

In the Joplin district of Missouri, 3 per cent "sheet ground" is considered to be a good paying proposition, worked on a scale of over 400 tons per day, and the ore bodies are only from 3 to 60 feet thick. Most of the "sheet ground" averages much less than 3 per cent, and runs as low as 1.35 per cent, are worked profitably from a 12-foot thick ore body, and milled at the rate of 600 tons per day, whereas, as above, East Tennessee ore is in large bodies and of a higher average grade for the large area.

At Aurora, Mo., Osgood, Carter & Company recently inspected a property operated by the Federal Lead Company, where they are milling a 2.63 per cent zinc ore at profit. This is about 30 miles from Joplin, and shows what can be done with lower grades and smaller bodies of zinc ores than are available in Eastern Tennessee.

In the Wisconsin zinc district, where Osgood, Carter & Company formerly operated large zinc mines and mills, the ore bodies are smaller, and the ores are higher grade. The richness of the ore bodies compensates to some extent, on an average, the low costs of mining Tennessee large ore deposits. For instance, the Wisconsin zinc ore body may average 15 per cent zinc, the ore may be only 1 foot thick, whereas a Tennessee ore body of 4 per cent grade may be 50 feet thick.

The ore from all of the above districts, excepting the Tennessee district, contains iron and lead as well as zinc. Shipments of carloads of 30 tons each in large quantities of Tennessee zinc concentrates show a record of 0.5 per cent to 1.5 per cent iron, and no lead, and such concentrates are in great demand for especially pure grade of spelter or metallic zinc.

## THE SMELTING OF TENNESSEE ZINC ORES IN TENNESSEE.

The smelting of Tennessee zinc ores in Tennessee is inviting commercially, as is shown by the results of operation of the small smelter at Clinton, operated by the Eades, Mixter & Healds Company. Coal supplies in great abundance are procurable from many mines within 40 miles, having a railway freight rate of 75 cents, less than the 85 cent rate from the Joplin mines to the Kansas gas belt zinc smelters. The freight rates on the finished slabs of zinc also is less from Tennessee to New York and the Atlantic coast seaboard points of consumption than from the Western smelters. The market for sulphuric acid, the chief by-product of a zinc smelter, is close to Clinton, large amounts being used by the southern fertilizer works in Middle Ten-

nessee. The Tennessee Copper Company, only in March last, closed a large contract with the fertilizer combination for all the sulphuric acid it could produce, which combine also uses large quantities of acid that are now shipped in from the northern smelting points in Illinois, Ohio and Kansas.

The grade of spelter or metallic zinc made from Tennessee ores is unusually pure, and is said to have always brought at least 2 cents per pound more than the standard market price for other spelters, such as the western brands. The following chemical analysis of spelter that was made at the Clinton smelter (closed during the panic of 1893 and never reopened) shows an exceptional high grade.

(1) Analysis made at Boston by State Assayer S. P. Sharpless:

| | Per Cent. |
|---|---|
| Zinc | 99.723 |
| Lead | 0.238 |
| Iron | 0.039 |

Sample is free from arsenic, antimony, manganese and other impurities.

(2) Analysis by Ledoux & Rickets, of New York, in duplicates:

| | Per Cent. |
|---|---|
| Zinc | 99.988 |
| Iron | 0.017 |
| | 100.000 |

Sample free from lead, copper, cadmium, arsenic, antimony, sulphur, etc.

Comparative figures will show the profits of zinc smelting in Tennessee to be proportionately greater than is now being made in the Kansas smelters close to the Joplin, or other Missouri zinc fields.

The net profits of smelting 40 tons of Tennessee concentrates daily amounts to $540, and the installation of a plant of this capacity would cost about $100,000.

East Tennessee as a field of investment in the zinc industry is thus shown to be one of great possibilities. The chief features of the inviting outlook for capital is the size of the ore bodies and the consequent assurance of a supply of raw material to last for years.

## TABLE OF COMPARATIVE SMELTING PROFITS.

| JOPLIN SMELTERS PRACTICE with 95% furnace efficiency | | TENNESSEE ZINC SMELTING with 90% furnace efficiency | | with 95% furnace efficiency | |
|---|---|---|---|---|---|
| | LB. | | LB. | | LB. |
| 1 ton of ore assaying 60% zinc contains metallic zinc or spelter amounting | 1,200 | 1 ton of ore assaying 55% zinc contains metallic zinc or spelter amounting | 1,100 | Same | 1,100 |
| Furnace efficiency (saving) 95%, or amounting to salable slabs of zinc | 1,140 | Furnace efficiency (saving) 90%, or amounting to salable slabs of zinc | 990 | Furnace efficiency 95%, gives salable spelter | 1,045 |
| Value at New York with 5-ct. spelter | $57 00 | Value at New York with 5-ct. spelter | $49 50 | Value at New York with with 5 ct. spelter | $52 25 |
| Cost of ore | $40 00 | Cost of ore | $31 00 | | |
| Cost of smelting and freight | $11 00 | Cost of smelting and freight | $11 00 | Same costs | $42 00 |
| | $51 00 | | | | |
| Net profits from zinc | $ 6 00 | Net profits from zinc | $ 7 50 | Net profits from zinc | $10 25 |
| Profits from acids at least | $ 6 00 | Profits from acids at least | $ 6 00 | Profits from acids at least | $ 6 00 |
| Total net smelting profits, per ton | $12 00 | Total net smelting profits, per ton | $13 50 | Total net smelting profits, per ton | $16 25 |

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